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Mineral Resource Report 83

1983

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RECONNAISSANCE SURVEY OF POTENTIAL CARBONATE WHITING SOURCES IN PENNSYLVANIA

Samuel W. Berkheiser, Jr.

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL RESOURCES
OFFICE OF RESOURCES MANAGEMENT
BUREAU OF
TOPOGRAPHIC AND GEOLOGIC SURVEY
Arthur A. Socolow, State Geologist

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RECONNAISSANCE SURVEY OF POTENTIAL CARBONATE WHITING SOURCES IN PENNSYLVANIA

by **Samuel W. Berkheiser, Jr.**
Pennsylvania Geological Survey

PENNSYLVANIA GEOLOGICAL SURVEY

FOURTH SERIES

HARRISBURG

1983

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ISBN: 0-8182-0024-3

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PREFACE

Data collected, compiled, and interpreted in this report are intended primarily for the users and producers of pulverized white carbonate rock; for example, the plastics, paints, adhesives, carpet backing, rubber, joint filler, and paper industries. The reconnaissance information presented in this report should be of value to anyone exploring for this specialized type of carbonate resource in Pennsylvania.

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RECONNAISSANCE SURVEY OF POTENTIAL CARBONATE WHITING SOURCES IN PENNSYLVANIA

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ABSTRACT

Carbonate rocks ranging in age from Precambrian to Triassic were investigated to determine if there is potential for their use as mineral fillers and whiting. Nineteen samples from 14 Paleozoic sources in southeastern Pennsylvania were analyzed for whiteness, dry brightness, and chemical characteristics.

Brightness and whiteness values were determined by industry producers from samples ground so that 100 percent of the material passed the 80-mesh (0.177-mm) sieve. Data interpreted from this coarsely ground material suggest that eight samples representing seven sources have good potential. Presently there are three producers in the York area that manufacture pulverized carbonate from a limestone unit of the Cambrian Kinzers Formation. This formation should be a primary exploration target for whiting west of the Susquehanna River. Massive and pure carbonate beds that have good potential exist in the Lower Paleozoic(?) Cockeysville Marble in the southeastern part of the state, where they occur as both dolomite or limestone and are associated with other less pure carbonate beds. Results obtained from a quarry in the Harrisburg area indicate that acceptable limestone also is present in the Ordovician St. Paul Group. Lateral continuity, thickness, and origin of these beds have not yet been fully evaluated.

Except for the removal of obvious weathered and stained surfaces, the carbonate samples were not altered prior to the initial tests. Weathering, especially in abandoned quarries and outcrops, was a major source of contamination.

Reflectance values for brightness and whiteness probably could be increased by (1) obtaining unweathered rock, (2) finer grinding to the standard gradation, and (3) other beneficiation techniques.

According to U.S. Bureau of Mines data (Singleton, 1981), the average price for crushed limestone used as whiting was $27.62 per short ton in 1979 and $31.14 per short ton in 1981. Relatively small tonnages can form a large reserve base. The recent annual total production of carbonate whiting in the United States is estimated to be in the range of 700,000 to 1,000,000 tons per year.

INTRODUCTION

PURPOSE AND SCOPE

The primary objective of this reconnaissance was to identify carbonates that have potential as high-brightness mineral fillers and whiting.

The term "whiting" was originally restricted to a very finely pulverized chalk. However, today the name is generally considered to include most finely ground, high-purity carbonates. Traditional users of carbonates as mineral fillers include the paint, plastics, rubber, putty, adhesives, textiles, and paper industries (Key, 1960). In the last 30 years there has been a general increase in the consumption of carbonate fillers. The plastics and paper industries may have the greatest future growth potential for the pulverized carbonate industry.

Presently there are three known whiting producers in the Commonwealth, all located in the greater York area. The National Gypsum Company of West York, the Thomasville Stone and Lime Company of Thomasville, and the White Pigment Corporation of West York are all believed to be producing a carbonate whiting product derived from the middle limestone unit of the Cambrian Kinzers Formation.

Based on inquiries from industry and the public and the preliminary nature of this investigation, only carbonates were studied. Potential targets were limited to some high-calcium limestones and known marble occurrences. Preliminary prospects were chosen primarily from published descriptions of carbonate occurrences, and included rocks ranging in age from Precambrian to Triassic. For various reasons, such as nonexistent outcrop, dark color, thinness of the stratigraphic unit, and urbanization, samples were not collected and/or tested from all prospects visited.

Physical tests were made on 19 of the more promising samples to determine their whiteness and brightness. These samples were also analyzed for chemical characteristics. Preliminary magnetic beneficiation tests were run on seven of the samples selected on the basis of the results of the initial analyses.

The area of this study is within the Piedmont and Valley and Ridge physiographic provinces in southeastern Pennsylvania (Figure 1).

Field investigations and sample collecting were carried out in early 1981. Compilation and interpretation of most data were performed intermittently between April and October of 1981.

ACKNOWLEDGEMENTS

The Pennsylvania Geological Survey is indebted to the Genstar Stone Products Company, Pfizer Minerals, and the White Pigment Corporation

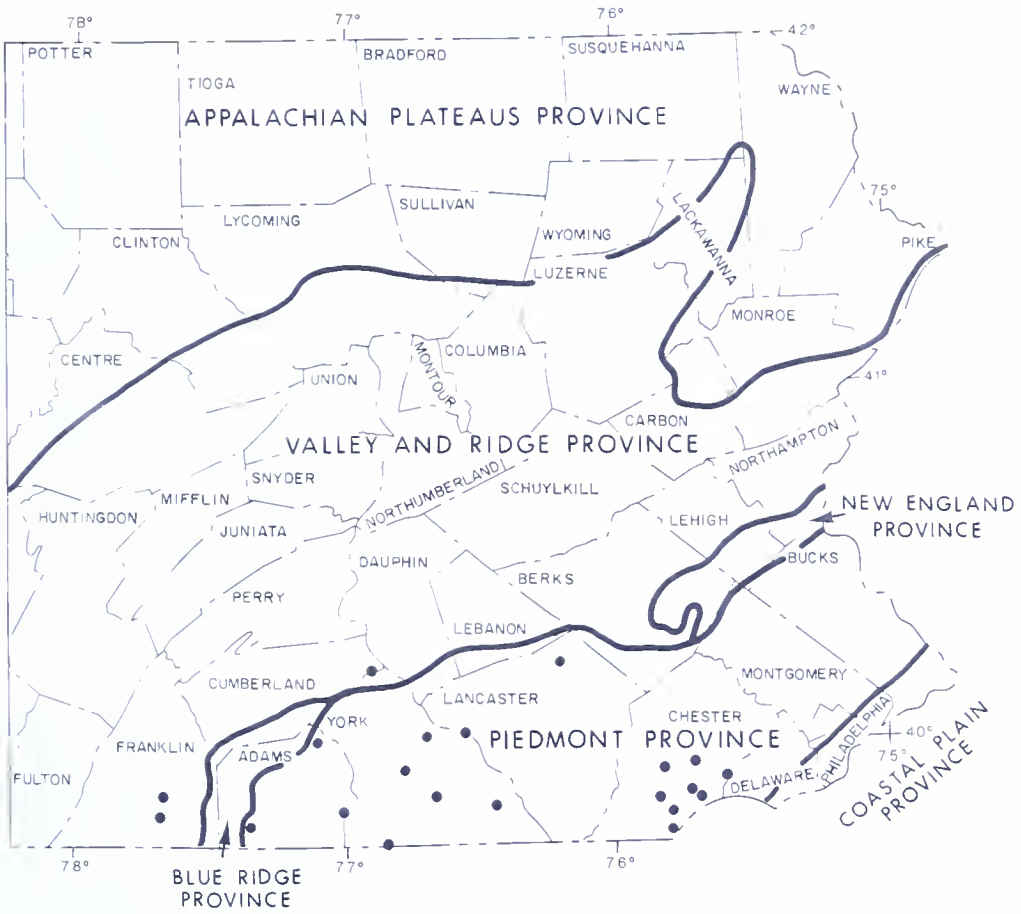


Figure 1. Physiographic provinces of eastern Pennsylvania and location of prospects investigated.

for determining dry brightness and whiteness values for blind samples submitted to them.

Dr. Robert C. Smith, II, Chief of the Mineral Resources Division, Pennsylvania Geological Survey, suggested the project, assisted with some field reconnaissance, and reviewed the manuscript. Mr. Leslie T. Chubb, Laboratory Technician, Mineral Resources Division, assisted with some field work and prepared samples for physical tests and chemical analysis. Dr. Arthur A. Socolow, Director of the Survey, and Mr. John H. Barnes, Geologist, Mineral Resources Division, provided valuable suggestions and reviewed the manuscript. In addition, Mr. Nelson R. Shaffer, Geologist, Coal and Industrial Minerals Section, Indiana Geological Survey, and Dr. Jonathan H. Goodwin, Geologist, Industrial Minerals Section, Illinois State Geological Survey, provided reviews of the manuscript which greatly assisted in improving the report.

The U.S. Bureau of Mines provided the chemical analyses listed in the report.

SAMPLE PREPARATION AND ANALYSES

SAMPLE PREPARATION

Initial sample preparation by the Pennsylvania Geological Survey consisted of washing and cleaning all field samples. All composite samples were weighed. Badly weathered areas were ground as clean as possible with a coarse silicon carbide wheel.

All material collected for each sample was crushed in a jaw crusher. A riffle splitter was used to separate samples for brightness tests, chemical analyses, and reserve stock. The sample splits for brightness and chemical analyses were pulverized so that 100 percent of the material passed the 80-mesh sieve, using a Braun pulverizer with ceramic plates. Although this procedure does not meet the technical specifications for pulverized limestone (minimum fineness of 97.0 percent passing a 325-mesh sieve), it was felt that a preliminary indication of the whiting potential of each sample could be gained from this information. All subsamples were labeled and sent to the respective laboratories for analyses.

BRIGHTNESS AND WHITENESS TESTS

Brightness and whiteness test results are recorded without reference to which of the participating companies provided them. Standard methods of the Pulverized Limestone Association were followed by all three companies. Hand compaction was necessary due to the coarseness of grind (100 percent passing 80-mesh sieve). All laboratories used barium sulfate as the primary standard and determined whiteness and brightness values on a Hunter colorimeter. Historically, there have been some difficulties within the Pulverized Limestone Association and the whiting industry with respect to reproducibility of data (brightness and whiteness).

CHEMICAL ANALYSES

Major- and minor-oxide analyses were determined by the U.S. Bureau of Mines Reno Research Center in Reno, Nevada, using inductively coupled plasma spectrometer analysis. Results for SiO_2, Al_2O_3, total Fe as Fe_2O_3, MgO, CaO, Na_2O, K_2O, TiO_2, and MnO were determined for 19 samples.

BENEFICIATION TESTS

Seven samples were selected for magnetic beneficiation after the physical test results from the initial samples were interpreted. The visual mineralogical descriptions of the magnetic-tailings fraction indicate the potential for beneficiation.

Testing procedures began with particle sizing, for ease of operation, to the range between minus-20 mesh and plus-80 mesh. Testing was conducted using a Frantz Isodynamic magnetic separator at an amperage setting of 1.45, the side slope varying between 0.2 and 1.5 degrees and the front slope at 15 degrees. One pass was made through the separator. The nonmagnetic fraction was ground so that 100 percent of the material passed the 80-mesh sieve and was tested for brightness and whiteness using the procedure listed above in the section on brightness and whiteness tests. Preliminary quantitative tests by industry proved equivocal, and comparative eyeball rankings of whiteness were substituted because a visual difference between some of the beneficiated samples and some of the unbeneficiated samples was unmistakable.

SAMPLE DATA AND TEST RESULTS— A DISCUSSION

Relative rankings of test results for whiteness and brightness are useful for determining which sources may have the greatest potential (Tables 1 and 2). However, within the pulverized-limestone industry, test results for whiteness and brightness usually vary somewhat between producers. The manufacturers recognized this problem and formed the Pulverized Limestone Association, which, among other things, is actively engaged in developing and promoting standard testing procedures. Because of a number of variables that are difficult to control and standardize, there is still a problem with direct comparison of test results from different laboratories. The range of whiteness values reported by the three laboratories for the same samples illustrates this problem (Table 2). Brightness values have less of a range; the maximum difference for a given sample is only about 2 points (Table 1).

Weathering and staining pose another problem with respect to testing of samples from outcrops. Outcrops at which the exposed rock is fresh and unweathered, as in the developed face of an active quarry, are rare. Most of the sites that were examined are abandoned quarries, where only weathered rock could be sampled. Hence, it may be assumed that brighter reflectance values would have resulted if fresh quarry samples had been available. The exceptions, of course, are the samples from the active quarries of the Bethlehem Mines Corporation, Hempt Brothers, Inc., Lancaster Lime and Stone Corporation, and White Pigment Corporation.

Brightness and whiteness values for most samples tested could also probably be increased a few points by finer grinding. By definition, a pulverized limestone must be ground fine enough so that a minimum of 97.0 percent of

Table 1. *Ranking of Brightness Values by Sample and Laboratory*

LABORATORY A		LABORATORY B		LABORATORY C	
Sample no.[1]	Brightness	Sample no.	Brightness	Sample no.	Brightness
17-81	95.6	17-81	94.4	17-81	94.7
7-81	93.2	2-81	90.2	7-81	92.0
2-81	91.7	13-81	90.1	2-81	91.1
13-81	91.6	7-81	89.9	13-81	91.0
18-81	91.2	18-81	89.8	18-81	90.5
16-81	91.1	8-81	89.8	16-81	90.4
8-81	90.8	16-81	89.8	8-81	90.3
12-81	90.8	9-81	89.6	12-81	90.3
6-81	90.7	12-81	89.5	9-81	89.9
9-81	90.6	1-81	89.0	6-81	89.6
1-81	89.7	6-81	88.7	1-81	89.3
15-81	89.5	15-81	88.3	15-81	88.9
16B-81	87.5	16B-81	87.6	16B-81	86.1
10-81	84.7	10-81	83.5	10-81	84.3
14-81	84.7	14-81	82.6	14-81	83.8
3-81	81.9	3-81	79.6	3-81	81.2
4-81	75.7	5-81	73.6	4-81	75.1
5-81	74.6	4-81	72.9	5-81	74.1
11-81	44.3	11-81	44.0	11-81	44.4

The median brightness ranking, in decreasing order, is 17-81, 7-81, 2-81, 13-81, 18-81, 16-81, 8-81, 12-81, 9-81, 6-81, 1-81, 15-81, 16B-81, 10-81, 14-81, 3-81, 4-81, 5-81, and 11-81. This ranking was obtained from the median of the three reported values for each sample.

[1] See Table 8 (Appendix) for the location, formation, sample type and interval, and comments.

the material passes a 325-mesh (0.044-mm) sieve. As mentioned previously, in this study the analyzed material was only ground fine enough so that 100 percent of the material passed an 80-mesh (0.177-mm) sieve.

No beneficiation was done in the initial tests other than washing and attempting to eliminate severely weathered surfaces by use of a grinding wheel. Some samples would probably increase in whiteness and brightness if beneficiation was economically feasible. Elimination of the phlogopite from the samples taken at many Cockeysville Marble sites might have a significant positive effect on the values. Elimination of dolomite from many of the samples from the Kinzers Formation would also have a significant effect on these limestone marbles of York and Adams Counties.

Mineralogical determinations were made visually unless otherwise noted. The major, minor, and trace classification of observed mineralogy is not meant to be quantitative. It roughly corresponds to the following: major,

Table 2. *Ranking of Whiteness Values by Sample and Laboratory*

LABORATORY A		LABORATORY B		LABORATORY C		EYEBALL[1]
Sample no.[2]	Whiteness	Sample no.	Whiteness	Sample no.	Whiteness	Sample no.
17-81	97.9	17-81	93.3	17-81	93.5	17-81
7-81	96.7	18-81	85.4	18-81	86.0	12-81
2-81	95.9	12-81	84.4	12-81	85.4	7-81
13-81	95.8	13-81	81.8	7-81	82.9	9-81
16-81	95.6	7-81	81.1	13-81	82.7	16-81
18-81	95.6	2-81	79.9	2-81	80.4	8-81
8-81	95.5	9-81	79.5	16-81	79.8	15-81
6-81	95.4	16-81	79.2	9-81	79.7	1-81
12-81	95.4	15-81	77.6	15-81	77.9	2-81
9-81	95.3	10-81	76.6	10-81	77.3	13-81
15-81	94.8	8-81	76.5	8-81	77.1	18-81
1-81	94.8	16B-81	75.7	1-81	75.1	6-81
16B-81	93.7	1-81	75.3	16B-81	73.9	16B-81
14-81	92.2	6-81	72.6	6-81	73.1	14-81
10-81	92.2	3-81	65.8	14-81	67.1	3-81
3-81	90.6	14-81	65.7	3-81	66.4	10-81
4-81	87.2	4-81	60.7	4-81	61.7	4-81
5-81	86.5	11-81	42.6	11-81	42.4	5-81
11-81	66.8	5-81	42.2	5-81	41.9	11-81

The median whiteness ranking, in decreasing order, is 17-81, 18-81, 12-81, 7-81, 13-81, 2-81, 16-81, 9-81, 15-81, 10-81, 8-81, 16B-81, 1-81, 6-81, 14-81, 3-81, 4-81, 11-81, and 5-81. This ranking was obtained from the median of the three reported values for each sample.

[1] Comparative visual ranking by three survey staff members under indoor fluorescent lighting. Listed in decreasing order of estimated whiteness.

[2] See Table 8 (Appendix) for location, formation, sample type and interval, and comments.

greater than 10 percent; minor, between 10 and 1 percent; and trace, less than 1 percent.

ADAMS AND YORK COUNTIES

Significant test results are from samples believed to be from the middle limestone unit of the Cambrian Kinzers Formation. However, pre-1944 published geologic maps may locally designate the Cambrian Ledger Formation as the underlying bedrock.

Three companies are known to be currently producing pulverized-limestone products from the Kinzers Formation. They are the National Gypsum Company, York; the Thomasville Stone and Lime Company, Thomasville; and the White Pigment Corporation, York.

Jonas and Stose (1930), Stose (1932), Stose and Jonas (1939), and Stose and Stose (1944) recognized three main units of this formation locally: a black to dark-gray shale at the base, a carbonate of variable texture and composition in the middle, and an argillaceous, quartzose limestone in the upper part. The middle carbonate unit locally becomes the white recrystallized marble that the whiting industry in Pennsylvania currently exploits.

Unfortunately, the stratigraphic and structural relationships of the Cambrian carbonate belt are not fully understood. Lack of outcrop, urbanization, and complex geology have not been conducive to systematic exploration for a whiting source in Adams and York Counties.

WHITE PIGMENT CORPORATION

Sample 17–81

LOCATION: Active quarry southwest of West York, about 4,500 feet (1,400 m) east of the intersection of U.S. Route 30 and Pa. Route 462, about 7,100 feet (2,200 m) northeast of Graybill, and about 1.8 miles (2.9 km) northwest of Indian Rock Dam in West Manchester Township, York County (Figure 2).

Quadrangle: West York
Latitude: 39°56′15″N Longitude: 76°46′58″W

TYPE OF EXPOSURE AND SAMPLE COLLECTED: Narrow, deep, active quarry having indistinct bench development. Bedding is obscure, but probably dips steeply to the north. A high-grade composite sample was obtained from a muck pile in the western portion of the quarry. The rock sampled was probably blasted from the north face, which has the deepest quarry development.

STRATIGRAPHY: The bedrock in the quarry has been mapped as Cambrian Ledger Formation (Stose and Jonas, 1939); however, it is probably the underlying Cambrian Kinzers Formation.

LITHOLOGY: White to very light gray, fine-grained calcareous marble; contains some dolomite crystals, mottling, and some pyrite blebs.

MINERALOGY:
Major: Calcite
Minor: Dolomite
Trace: Pyrite

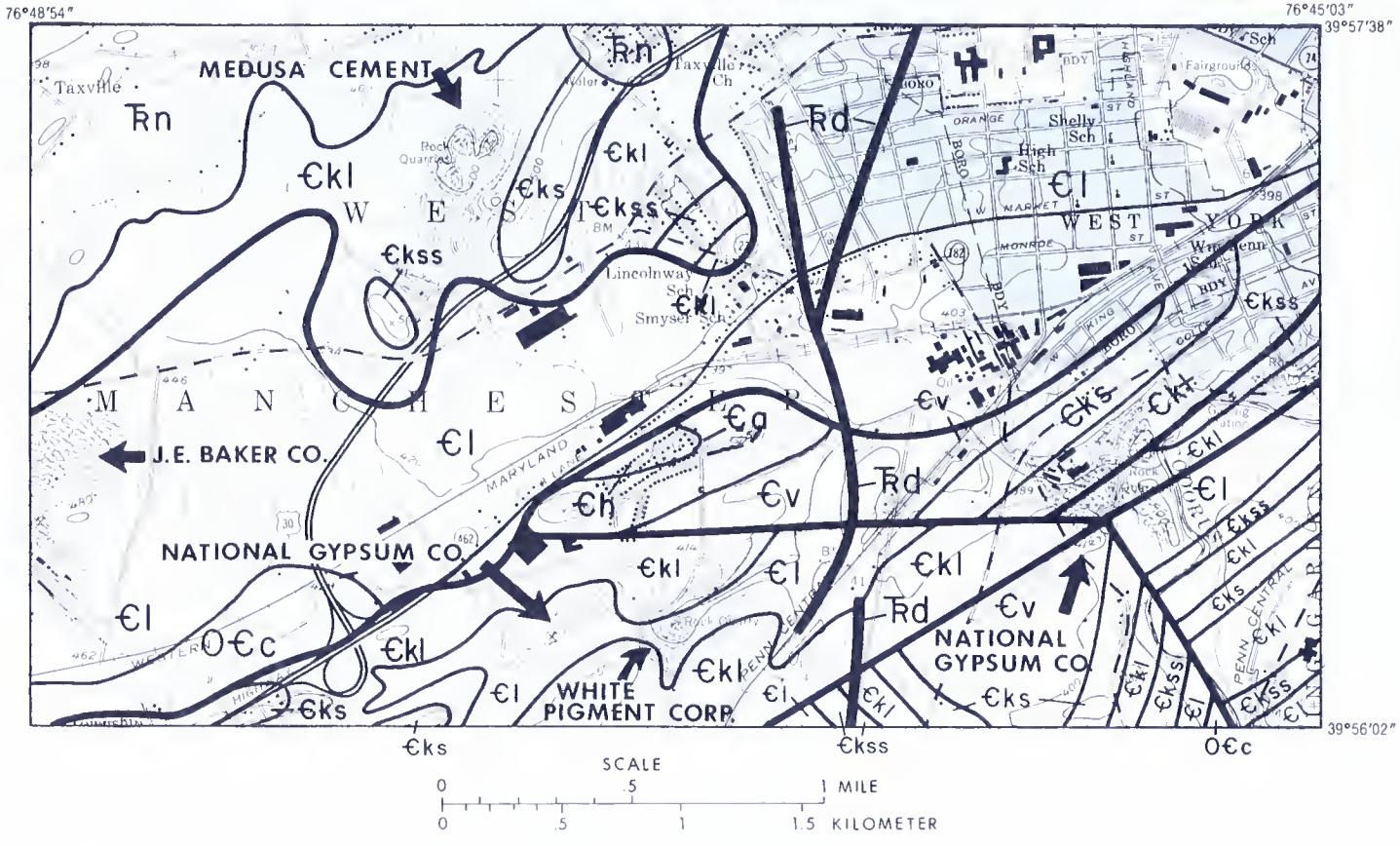


Figure 2. Geologic and location map of the active White Pigment Corporation quarry, West York, York County. Geology from Stose and Jonas (1939), with revisions by Wilshusen (1979).

PHYSICAL TEST RESULTS:

	Dry brightness	*Whiteness*
Laboratory A	95.6	97.9
Laboratory B	94.4	93.3
Laboratory C	94.7	93.5

CHEMICAL TEST RESULTS:

CaO	=	54.3% ($CaCO_3$ = 96.9%)	Na_2O	=	<100 ppm
MgO	=	1.3% ($MgCO_3$ = 2.7%)	K_2O	=	0.18%
SiO_2	=	2.6%	MnO	=	28 ppm
Fe_2O_3	=	0.11%	TiO_2	=	220 ppm
Al_2O_3	=	0.46%	TOTAL	=	103.0%

CONCLUSIONS AND REMARKS: This hand-picked, high-grade sample from an active whiting producer was included for comparison purposes. Only the whitest rock fragments that had the least amount of visual contamination were included. Brightness and whiteness values for this sample are the highest tested. Mill run values for this operating whiting producer may be lower because the sample was a composite of the best material available from a muck pile, probably produced from a stratigraphic level well below the zone of weathering. Results from chemical analyses reveal that the total SiO_2, Al_2O_3, and Fe_2O_3 contents for this sample are greater than those for any of the promising samples tested from Cambrian carbonates elsewhere in the Adams-York County area. Presently there is not a satisfactory explanation for these results.

The quarry, which was purchased from H. E. Williams and opened in 1949, is in an area of very complex geology. The general strike appears to be northeast-southwest; bedding is very difficult to recognize in the mostly mottled white limestone. Previous mapping suggests that the structural setting is a synclinorium that has a thin sequence of dolomite at the surface (Stose and Jonas, 1939). Gordon (1922) reported calcite, dolomite, quartz, fluorite, barite, serpentine, talc, pyrite, chalcopyrite, galena, sphalerite, malachite, gypsum, and nitrocalcite from quarries west of York. Except for calcite, dolomite, and quartz, these minerals were probably observed only in trace amounts. There are several nearly vertical Triassic diabase dikes less than 3 ft (1 m) thick in the quarry; these do not appear related to the observed recrystallization of the marble.

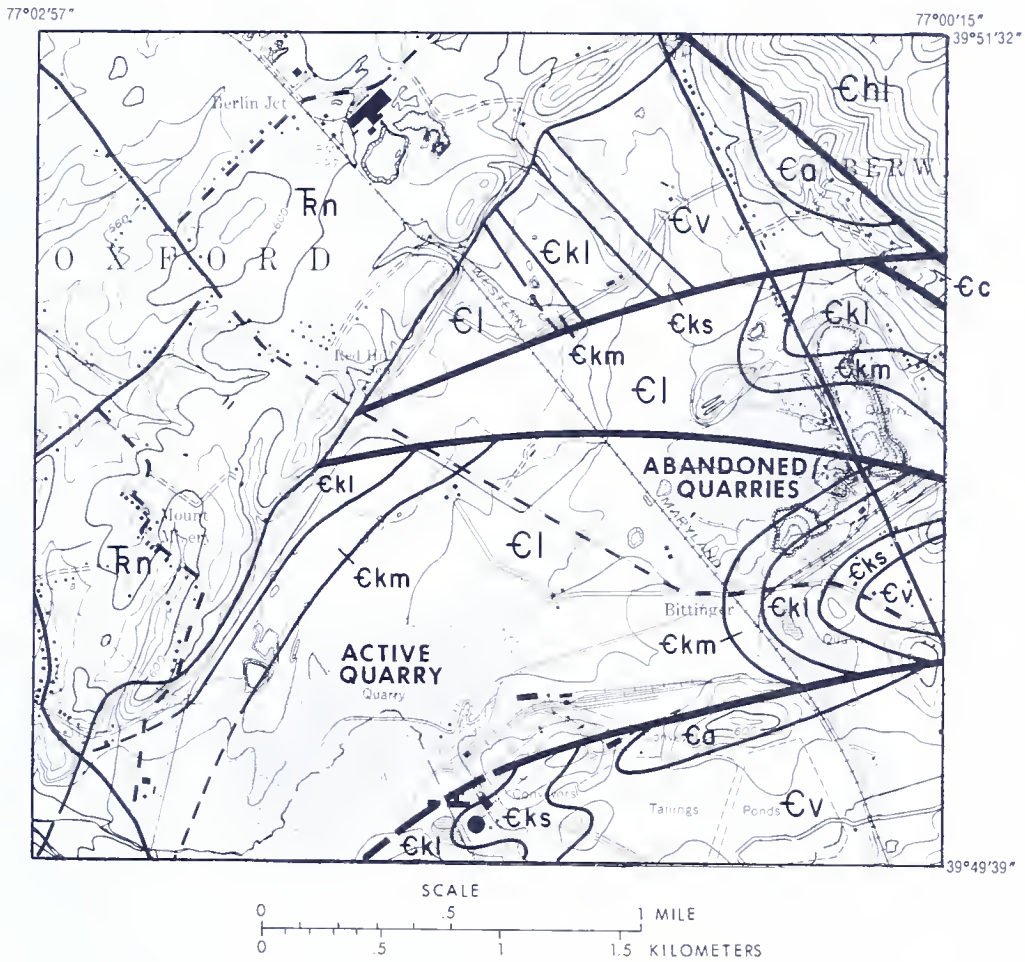
BETHLEHEM MINES CORPORATION

Sample 12–81

LOCATION: Active quarry northwest of Hanover, about 1 mile (1.6 km) west-southwest of Bittinger, about 1 mile (1.6 km) southeast of Irishtown,

about 1 mile (1.6 km) north of Edgegrove, and about 2.1 miles (3.4 km) north-northwest of McSherrystown, in Oxford and Conewago Townships, Adams County (Figure 3).

Quadrangle: McSherrystown
Latitude: 39°50′00″N Longitude: 77°02′00″W



EXPLANATION

- Trn — New Oxford Formation, shale, sandstone, and conglomerate
- €l — Ledger Formation, dolomite
- €km — Kinzers Formation, white marble
- €kl — Kinzers Formation, limestone
- €ks — Kinzers Formation, shale
- €v — Vintage Formation, dolomite
- €a — Antietam Formation, sandstone
- €c — Chickies Formation, quartzite
- €hl — Hellam Conglomerate, quartzose

Figure 3. Geologic and location map of the Bethlehem Mines Corporation Hanover quarry, Adams County. Geology from Stose and Bascom (1929) and Stose and Stose (1944).

TYPE OF EXPOSURE AND SAMPLE COLLECTED: Active quarry in which three major levels of mining have been developed. The attitude, thickness, and continuity of beds are generally unknown. Most of a 90-foot-(30-m-) high face has white marble exposed for about 200 feet (60 m) subparallel(?) to strike. Tectonic breccia is common in this zone. A composite sample was taken from a muck pile below an active face (Figure 4).

STRATIGRAPHY: Mapped as Cambrian Ledger Formation (Stose and Bascom, 1929; Stose, 1932; Stose and Stose, 1944; and Miller, 1934).

LITHOLOGY: White to very light gray, fine-grained calcareous marble containing some dolomite mottling, some calcite crystals, sparse limonite blebs after pyrite, rare ooliths, and some tectonic breccia. The attitude of the beds is chaotic.

MINERALOGY:
Major: Calcite
Minor: Ferroan dolomite
Trace: Pyrite and limonite

PHYSICAL TEST RESULTS:

	Dry brightness	*Whiteness*
Laboratory A	90.8	95.4
Laboratory B	89.5	84.4
Laboratory C	90.3	85.4

CHEMICAL TEST RESULTS:

CaO	= 54.5% ($CaCO_3$ = 97.3%)	Na_2O	= 200 ppm (value is near limit of detection)
MgO	= 1.1% ($MgCO_3$ = 2.3%)		
SiO_2	= <90 ppm	K_2O	= <500 ppm
Fe_2O_3	= 270 ppm	MnO	= 72 ppm
Al_2O_3	= 330 ppm	TiO_2	= 45 ppm
		TOTAL	= 99.8%

CONCLUSIONS AND REMARKS: The brightness and whiteness values for the sampled interval indicate that the rocks here might be used to produce whiting. This is not surprising, because this sequence of carbonates is the southwestern strike-belt extension of the producing horizon in West York. Development of a whiting source on these premises might conflict with current production of high-calcium lime. However, these large quarries provide an extraordinary exposure of favorable carbonate sequences, and the chemical purity and exceptionally low SiO_2 and Fe_2O_3 values at the sampled interval suggest that other uses may be possible for this stone.

The Bethlehem Mines Corporation also controls the now-inactive quarries northeast of Bittinger and a quarry southeast of Bittinger. All of these

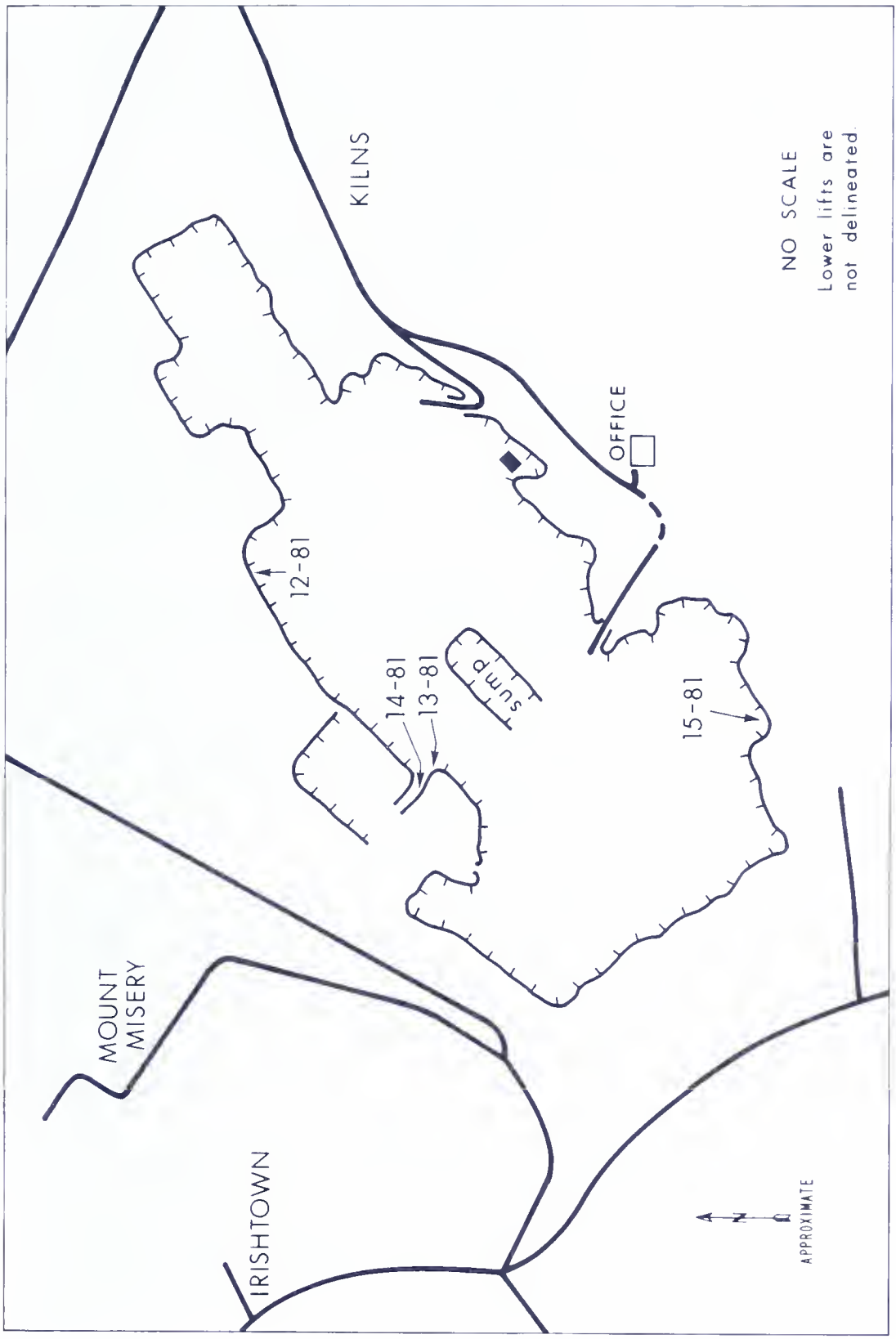


Figure 4. Sketch map of sample locations, Bethlehem Mines Corporation Hanover quarry.

quarries are connected by underground tunnels beneath the highways. Because of partial flooding, the quarry east of Pa. Route 94 and the quarry southeast of Bittinger are inaccessible; the tunnels, now submerged, were the only remaining means of access. The two quarries (Figure 3) west of Route 94 and northeast of Bittinger have been expanded to one large quarry, and small areas are accessible for sampling and investigation.

Stose (1932, p. 121) reported that the rock in the John R. Bittinger quarry is "a mixture of blue, fine-grained limestone and white crystalline marble, both high-calcium lime-rock, and granular gray dolomite. These rocks are intricately mixed, the dolomite and the pure limestone being not only closely folded together but apparently they also grade laterally into each other." When John Bittinger operated the quarry, the high-calcium limestone was burned to lime and used in paper manufacture. Stose reported that other quarries in the area, such as Steacy and Wilton, Max Hoke and Son, and Jacob C. Shriver, contained pure white marble mixed with limestone and dolomite. Some of these quarries also produced a high-grade lime that was used in paper manufacture. It is difficult to locate these now-abandoned quarries from Stose's descriptions; however, some of them are probably now controlled by the Bethlehem Mines Corporation.

It is very difficult to ascertain stratigraphic thicknesses of the white marble beds due to structural as well as stratigraphic complexities.

BETHLEHEM MINES CORPORATION

Sample 13–81

LOCATION: Same as for sample 12–81. See Figure 4.

TYPE OF EXPOSURE AND SAMPLE COLLECTED: Active quarry in which three major levels of mining have been developed. The beds locally strike approximately N5°E and dip 65°SE. A composite face sample of about 35 feet (11 m) of stratigraphic thickness was taken along the access ramp, first lift from the top, on the north face (Figure 4). Sample 14–81 is separated from the sampled interval by about 18 feet (5.5 m) of gray impure limestone.

STRATIGRAPHY: Mapped as Cambrian Ledger Formation (Stose and Bascom, 1929; Stose, 1932; Stose and Stose, 1944; and Miller, 1934).

LITHOLOGY: Very light gray to white, fine-grained calcareous marble containing dolomite crystals and some discontinuous light-gray limestone laminations and mottling; staining that appears to be hematitic is present along fractures.

MINERALOGY:
Major: Calcite
Minor: Ferroan dolomite
Trace: Red staining; appears to be hematitic

PHYSICAL TEST RESULTS:

	Dry brightness	*Whiteness*
Laboratory A	91.6	95.8
Laboratory B	90.1	81.8
Laboratory C	91.0	82.7

CHEMICAL TEST RESULTS:

CaO	= 55.0% ($CaCO_3$ = 98.2%)	Na_2O	= 190 ppm (value is near limit of detection)
MgO	= 0.55% ($MgCO_3$ = 1.2%)	K_2O	= <500 ppm
SiO_2	= <90 ppm	MnO	= 87 ppm
Fe_2O_3	= 130 ppm	TiO_2	= 53 ppm
Al_2O_3	= 540 ppm	TOTAL	= 99.6%

CONCLUSIONS AND REMARKS: The brightness and whiteness values for the sampled interval indicate that the rocks might be used to produce whiting. Additional remarks are the same as for sample 12–81.

The nearby sampled interval for sample 14–81, which is separated from this sampled interval by gray impure limestone, is topographically and stratigraphically higher and has significantly lower whiteness values. This decrease could be the result of residual staining by red Triassic sediments which may have once overlain these carbonates.

BETHLEHEM MINES CORPORATION

Sample 15–81

LOCATION: Same as for sample 12–81. See Figure 4.

TYPE OF EXPOSURE AND SAMPLE COLLECTED: Active quarry in which three major levels of mining have been developed. Bedding appears to be nearly vertical, and beds thicken upward. A composite face sample of an exposure apparently representing about 38 feet (12 m) of stratigraphic thickness was taken from the southwestern portion of the quarry, on the first lift from the top (Figure 4).

STRATIGRAPHY: Mapped as Cambrian Ledger Formation (Stose and Bascom, 1929; Stose, 1932; Stose and Stose, 1944; and Miller, 1934).

LITHOLOGY: White to very light gray, fine-grained limestone marble. Some light-gray dolomite mottling and rare pyrite are present.

MINERALOGY:
Major: Calcite
Minor: Dolomite
Trace: Pyrite and red blebs that appear to be hematitic

PHYSICAL TEST RESULTS:

	Dry brightness	*Whiteness*
Laboratory A	89.5	94.8
Laboratory B	88.3	77.6
Laboratory C	88.9	77.9

CHEMICAL TEST RESULTS:

CaO	= 54.2% ($CaCO_3$ = 96.2%)	Na_2O	= 210 ppm (value is near limit of detection)
MgO	= 1.4% ($MgCO_3$ = 2.9%)	K_2O	= <500 ppm
SiO_2	= 1.0%	MnO	= 55 ppm
Fe_2O_3	= 330 ppm	TiO_2	= 60 ppm
Al_2O_3	= 630 ppm	TOTAL	= 100.8%

CONCLUSIONS AND REMARKS: The brightness values for the sampled interval indicate that the rocks might be used to produce whiting. However, the whiteness values indicate that the use of the rocks might be limited to opaque materials such as rubber, linoleum, and shingles. The sampled face was not fresh and contained organic material. An effort was made to obtain fresh rock, but for safety reasons this was not everywhere possible. Additional remarks are the same as for sample 12–81.

Nearby undeveloped farmland, mapped by Stose and Stose (1944) as Cambrian Kinzers Formation (''white marble''), could be a primary exploration target. The northwest-southeast-trending belt of carbonates about 4,000 feet (1,200 m) southeast of Berlin Junction is an example (Figure 3).

ABANDONED S. FORRY LAUCKS QUARRIES

Sample 16–81

LOCATION: Three abandoned quarries north of the U.S. Route 30 bypass, about 1,100 feet (340 m) northwest of the intersection of Bull Road and Foustown Road, and about 1.2 mile (1.9 km) southeast of Foustown, in Manchester Township, York County (Figure 5).

Quadrangle: West York
Latitude: 39°58′55″N Longitude: 76°45′27″W

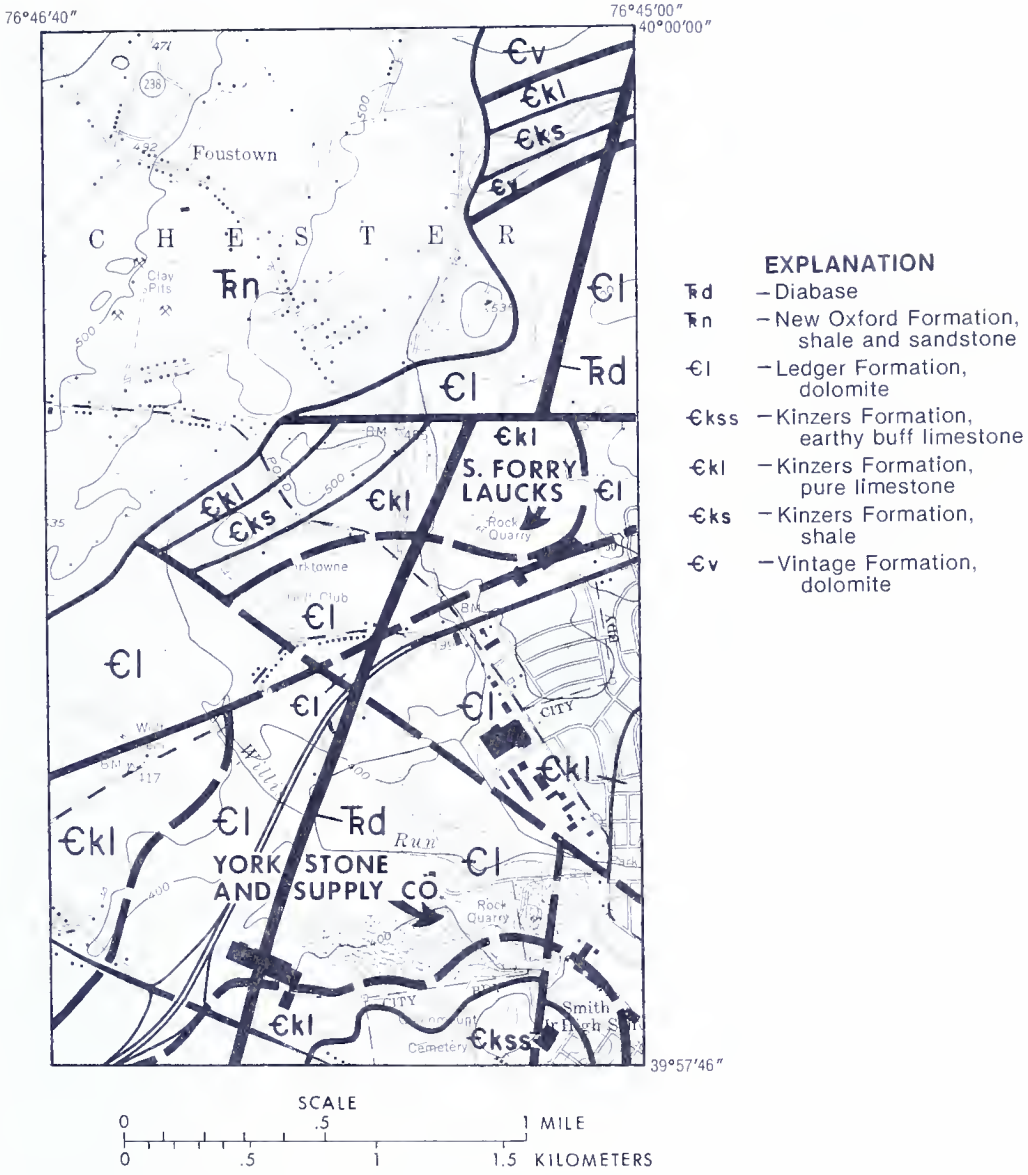


Figure 5. Geologic and location map of the S. Forry Laucks abandoned quarries, West York, York County. Geology from Stose and Jonas (1939), with revisions by Wilshusen (1979).

TYPE OF EXPOSURE AND SAMPLE COLLECTED: Southernmost and deepest abandoned quarry. These pits are overgrown and partially backfilled. Bedding is locally subhorizontal; cleavage relationships suggest that the units are not overturned. A composite face sample representing about 23 feet (7 m) of stratigraphic thickness was taken from the eastern face of the southwestern pit (Figure 6).

STRATIGRAPHY: Mapped as Cambrian Kinzers Formation (Stose and Jonas, 1939).

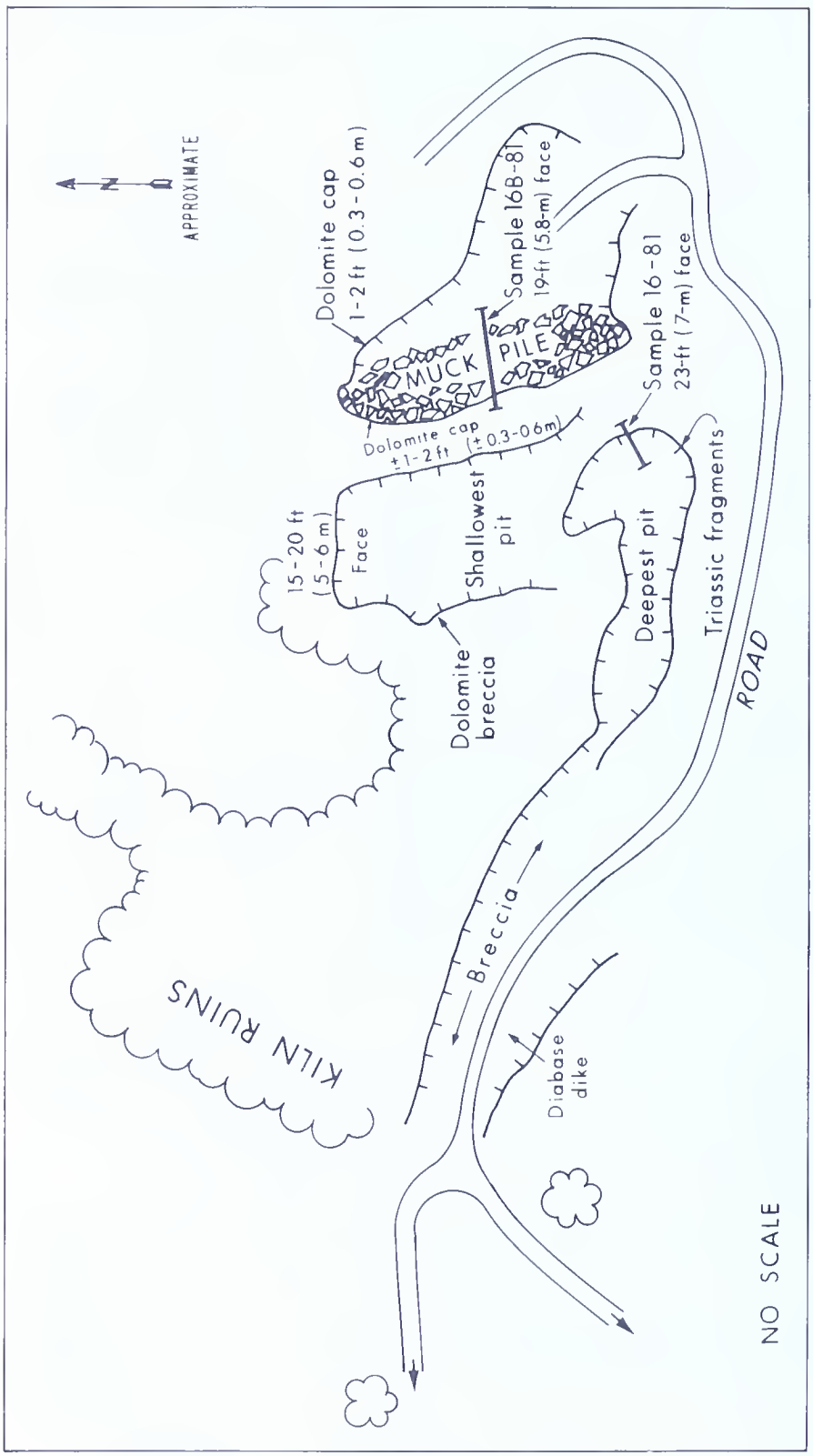


Figure 6. Sketch map of sample locations, S. Forry Laucks abandoned quarries.

LITHOLOGY: White to very light gray, mottled, fine-grained, saccharoidal, calcareous marble containing some dolomite crystals and rare pyrite blebs. Some red staining, which appears hematitic, is present along fractures. There is an exceptionally white bed, about 3 feet (1 m) thick, near the base of the sampled interval.

MINERALOGY:
Major: Calcite
Minor: Red staining, which appears to be hematitic, along fractures
Trace: Dolomite

PHYSICAL TEST RESULTS:

	Dry brightness	*Whiteness*
Laboratory A	91.1	95.6
Laboratory B	89.8	79.2
Laboratory C	90.4	79.8

CHEMICAL TEST RESULTS:

CaO	= 53.2% ($CaCO_3$ = 95.0%)	Na_2O	= 290 ppm (value is near limit of detection)
MgO	= 0.86% ($MgCO_3$ = 1.8%)		
SiO_2	= 1.8%	K_2O	= <500 ppm
Fe_2O_3	= 520 ppm	MnO	= 120 ppm
Al_2O_3	= 870 ppm	TiO_2	= 69 ppm
		TOTAL	= 98.8%

CONCLUSIONS AND REMARKS: The brightness and whiteness values for the sampled interval indicate that the rocks might be used to produce whiting. The pinkish tint, which appears to be hematitic, may be a near-surface phenomenon related to the nearby Triassic clastics.

The sampled interval is believed to be correlative with the producing horizons of the three whiting producers in West York and Thomasville. However, quarry development of this property may not be feasible because of the urbanization in the immediate area. Table 3 lists some brief descriptions and chemical analyses from 10 core holes drilled at unknown localities on the Laucks farm (Miller, 1934). As indicated by these data, there are seven holes that intercepted considerable thicknesses (50+ feet, or 15+ m) of white crystalline limestone. Characteristically, this limestone contains less than 1 weight percent of impurities.

There are several abandoned quarries further to the east in the Wrightsville area. The Beard Lime Company quarry, which was probably developed in the limestone member of the Kinzers Formation, was opened circa 1837 (Jandorf, 1912) and closed circa 1930 after an extensive landslide (Miller, 1934). Jandorf (1912) observed pyrite, hematite, limonite, chalcopyrite,

Table 3. *Description and Analyses of Core from the S. Forry Laucks Farm (from Miller, 1934, p. 706-707[1])*

Farm is located in West York, York County; core-hole locations are unknown.

	Feet	$CaCO_3$	$MgCO_3$	Al_2O_3 Fe_2O_3	SiO_2	P (for entire hole)
Hole No. 1—261 ft						
A. White, dense, crystalline stone	42	97.89	1.66	0.32	0.20	—
B. Grayish-blue stone	4	98.37	1.47	0.20	0.04	—
[2] C. Same as A	33	96.81	2.89	0.20	0.12	—
D. Approximately dolomite	1	59.20	40.25	0.44	0.11	—
E. White crystalline stone	33	96.87	2.76	0.15	0.25	—
F. Light-blue stone	38	95.72	3.97	0.20	0.17	—
G. Light-blue stone with pink discolorations	21	93.12	6.52	0.24	0.18	—
H. Blue stone, slightly darker than G	68	91.92	6.30	0.55	1.24	—
I. Dark-blue stone	22	83.82	14.24	0.63	1.39	—
J. Very dark blue stone, rather soft and graphitic	19	75.44	21.87	0.93	1.84	0.004
Hole No. 2—217 ft						
Overburden, 2 ft						
A. White crystalline stone	18	97.95	1.83	0.08	0.11	—
B. Dense, crystalline, gray stone, 2 ft						
Gray stone, 8 in.						
Gray stone, 6 in.						
Gray stone, 1 ft, 10 in	5	62.45	36.79	0.38	0.34	—
[2] C. White stone, 11 ft						
White stone, 1 ft						
Dense, white, crystalline stone, 53 ft; pinkish tints in spots; turns grayish toward lower 20 ft	65	96.89	2.83	0.31	0.17	—
D. Dense, grayish-white stone	71	96.14	3.43	0.27	0.12	—
E. Darker gray stone	44	85.76	12.46	0.50	1.30	—
F. Very dark blue stone, graphitic	12	76.16	21.79	0.66	1.50	0.005

Hole No. 3—263 ft						
Overburden, 2 ft						
[2]A. White crystalline stone with small blue inclusions	128	97.40	2.55	0.14	0.11	—
B. Gray, hard stone, 4 ft						
Gray stone, 3 ft	7	73.32	25.48	0.48	0.66	—
C. White stone, 3 ft						
White stone, 10 ft	13	93.44	6.02	0.25	0.36	—
D. Rather hard, gray stone, 57 ft						
Streaked with blue, 4 ft	61	62.51	34.54	0.73	2.33	—
E. Dense blue stone, 25 ft						
Dense blue stone, 27 ft	52	91.94	6.77	0.48	0.90	0.0045
Hole No. 4—150 ft						
Overburden, 7 ft						
[2]A. Dense, white, crystalline stone	79	96.55	3.06	0.19	0.22	—
B. Blue stone	16	97.00	2.64	0.13	0.17	—
C. Gray crystalline stone, dense but weathered in spots	48	73.11	25.90	0.76	0.11	0.0025
Hole No. 5—125 ft						
Overburden, 12 ft						
[2]A. Dense, white, crystalline stone with pinkish tint	44	96.91	3.68	0.15	0.23	—
B. Pinkish-gray stone with streaks of dense, white, crystalline stone	30	62.67	36.51	0.56	0.13	—
C. Dense gray stone	20	94.42	4.99	0.19	0.25	0.003
D. Siliceous, poor-looking stone, 19 ft	—	—	—	—	—	—
Hole No. 6—144 ft						
Overburden, 9 ft						
A. White stone	6	97.54	2.05	0.16	0.20	—
B. Gray crystalline stone	29	75.78	23.78	0.27	0.13	—
C. Blue stone, becoming darker with depth	65	92.80	5.89	0.44	0.92	—
D. Dark-blue stone	5	79.40	18.48	0.69	1.36	0.006
Hole No. 7—106 ft						
Overburden, 10 ft						
A. Dark-blue graphitic stone, slightly dolomitic	96	92.28	5.93	0.43	1.42	0.012

Table 3. *(Continued)*

	Feet	$CaCO_3$	$MgCO_3$	Al_2O_3 Fe_2O_3	SiO_2	P (for entire hole)
Hole No. 8—247 ft						
A. Dolomitic stone in spots	17	86.95	10.95	0.44	1.66	—
B. Dolomite, 3 ft						
Dolomite, 6 in.	3-1/2	55.66	43.03	0.64	0.74	—
C. White stone, 4 ft						
→ [2] White stone, 70 ft, 6 in.	74-1/2	96.04	2.90	0.24	0.78	—
D. White stone, siliceous in spots	52	88.43	3.22	0.20	8.22	—
E. Dolomite	4	57.69	40.99	0.44	0.72	—
F. Light-blue mottled stone	33	94.30	3.52	0.14	1.90	—
G. Dolomite	18	55.70	43.30	0.43	0.58	—
H. Rather poor looking dolomite	45	88.44	9.29	0.59	1.87	0.007
Hole No. 9—227 ft						
Overburden, 4 ft						
A. White crystalline stone	40	97.81	1.86	0.12	0.28	—
→ [2] B. Dolomite	6	63.84	33.96	0.71	1.48	—
C. White stone with pinkish discoloration	65	97.96	1.75	0.10	0.27	—
D. Dolomite	1	61.61	37.47	0.26	0.49	—
E. Dense white stone with grayish streaks	45	97.24	2.31	0.13	0.40	—
F. Grayish limestone	56	95.53	3.14	0.15	1.10	—
G. Dolomite, weathered	10	57.92	41.48	0.33	0.27	0.003
Hole No. 10—147 ft						
Overburden, 4 ft						
A. Hard, dense dolomite	143	55.01	43.42	1.09	0.34	0.010

[1] Minor modifications have been made to format, wording, and punctuation.

[2] Arrows indicate intercepts of white crystalline stone.

dolomite, calcite, quartz, and fluorite at this quarry. Both Jandorf (1912) and Miller (1934) reported approximate east-west strikes; however, the former reported a dip of 54°SE and the latter a dip of 55°SW. White marble beds were noted by both geologists. Stose and Jonas (1939) measured the section listed in Table 4 from exposures north of Wrightsville where the pure marble of the middle member was quarried. Interpretations from this data suggest that there may be about 80 feet (25 m) of white marble separated near the top by a 5-foot (1.5-m) light-gray dolomite bed.

It should be noted that there are additional abandoned quarries between York and Wrightsville, some of which are believed to be developed in the Kinzers Formation. The abandoned quarry of the York Valley Lime and Stone Company west of Hellam Station is reported to have contained white marble. These data suggest the existence of favorable whiting sources from Hanover east to the Susquehanna River.

ABANDONED S. FORRY LAUCKS QUARRIES

Sample 16B–81

LOCATION: Same as for sample 16–81. See Figure 6.

TYPE OF EXPOSURE AND SAMPLE COLLECTED: Easternmost abandoned pit. Bedding is locally subhorizontal. A composite sample was taken of a muck pile and the partially exposed western face (Figure 6). The total height of this interval is about 19 feet (5.8 m).

STRATIGRAPHY: Mapped as Cambrian Kinzers Formation (Stose and Jonas, 1939).

LITHOLOGY: White to very light gray, saccharoidal, calcareous marble containing some dolomite crystals, mottling, and minor blebs that appear to be hematitic.

MINERALOGY:
Major: Calcite
Minor: Dolomite
Trace: Blebs that appear to be hematitic

PHYSICAL TEST RESULTS:

	Dry brightness	*Whiteness*
Laboratory A	87.5	93.7
Laboratory B	87.6	75.7
Laboratory C	86.1	73.9

Table 4. *Composite Section of the Kinzers Formation and Overlying Limestones North of Wrightsville, York County (from Stose and Jonas, 1939, p. 54-55[1])*

Unit		Thickness (feet)
Conestoga Limestone		
Argillaceous limestone conglomerate and argillaceous banded blue limestone, and thick granular crystalline limestone Black argillaceous limestone and thin shale, ripple-marked Two-foot bed of marble Conglomerate of dark slabby limestone pebbles and large (6 in.) angular white marble masses in black slaty matrix		200±
Concealed (slaty limestone with shale partings in part; large spring near base)		220±
Ledger Dolomite		
White to blue-mottled, coarsely crystalline dolomite. (In quarry west of road on upland, 50 ft of dark argillaceous to earthy limestone, closely folded, makes a horse in quarry.)		105±
Kinzers Formation		
Upper member		
Dark slaty argillaceous limestone and hackly dark dolomite	10±	
Thin, fissile to platy, black earthy shale	5	
Earthy-banded, blocky, sandy limestone; weathers to hard, quartz-grain sandstone and porous sandstone pitted by dissolved limestone pebbles	20±	
Concealed	35±	
Black fissile shale and slaty limestone	40±	
Slaty blue limestone and knotty blue dolomite; rough bedding surfaces; carbonaceous partings	25	
		135±
Middle member		
Dark- and light-spotted crystalline marble ("leopard rock")	10	
→[2]Massive-bedded, white, coarsely crystalline marble	30±	
Light-gray dolomite (horse in quarry)	5	
→[2]Very massive bedded, mottled, white, coarsely crystalline marble; some limestone conglomerate in middle; thinner bedded at base	50±	
Blue limestone	10	
Concealed	80±	
		185±
Lower member		
Concealed	70±	
Dark shale (forms hill)	30±	
		100±
		420±
Vintage Dolomite		
Dark knotty dolomite		

[1] Minor modifications have been made to format, wording, and punctuation.

[2] Arrows denote potential whiting sources.

CHEMICAL TEST RESULTS:

CaO	= 53.5% ($CaCO_3$ = 95.5%)	Na_2O	= 250 ppm (value is near limit of detection)
MgO	= 0.86% ($MgCO_3$ = 1.8%)	K_2O	= <500 ppm
SiO_2	= 1.9%	MnO	= 120 ppm
Fe_2O_3	= 520 ppm	TiO_2	= 67 ppm
Al_2O_3	= 390 ppm	TOTAL	= 99.4%

CONCLUSIONS AND REMARKS: The brightness and particularly the whiteness of the sampled interval indicate that the rocks might be used to produce whiting. The staining, which appears to be hematitic, is presumably related to the Triassic clastic rocks and may be the cause of these lower values. This staining may diminish with depth. The Al_2O_3 and Fe_2O_3 are quite low for both sampled intervals (16–81 and 16B–81). See sample 16–81 and Table 3 for additional information.

CHESTER COUNTY

The Cockeysville Marble, probably of Early Paleozoic age, is the only formation investigated in Chester County that yielded significant test results. The Cockeysville was examined in five main outcrop belts or districts: Embreeville, Kennett Square, Avondale-West Grove, Landenberg, and Doe Run.

Some published geologic maps designate the isolated marble occurrences at Embreeville and east of Embreeville as Precambrian Franklin Marble. This is not consistent with lithologic associations observed in the field, and, for this report, they are considered Cockeysville Marble.

The Cockeysville Marble generally consists of a white or light-blue-gray limestone or dolomite, medium- to coarse-grained in most places and banded in many places. Phlogopite commonly occurs in discrete bands in these rocks. The total thickness of the carbonate is generally unknown. Bascom and Stose (1932) reported that it presumably does not exceed 500 feet (150 m), whereas Miller (1934) stated that it does not exceed 1,000 feet (300 m) in the Avondale area.

During the last quarter of the nineteenth century, at least 50 lime quarries were operating in the formation (Bascom and Stose, 1932). Many of the old vertical kiln foundations can still be seen in the fields and are a clue to the possible presence of nearby abandoned quarries.

ABANDONED LANDENBERG QUARRY

Sample 7–81

LOCATION: Abandoned open pit about 1.5 miles (2.4 km) southwest of Landenberg, about 1.2 miles (1.9 km) west of boundary monument 2-1/2

on the Pennsylvania-Delaware border, and 2,500 feet (760 m) south of the North Bank School in London Britain Township, Chester County (Figure 7).

Quadrangle: West Grove
Latitude: 39°45′29″N Longitude: 75°46′36″W

TYPE OF EXPOSURE AND SAMPLE COLLECTED: Abandoned and partially overgrown pit about 40 feet (12 m) deep. The attitude of the beds is subhorizontal, and they dip slightly to the north. A composite sample was taken of the basal 10 feet (3 m) of the northwest face (Figure 8).

STRATIGRAPHY: Mapped as Cockeysville Marble (Bascom and Stose, 1932), of probable Early Paleozoic age.

LITHOLOGY: White to very light gray, coarsely crystalline dolomitic marble. Some phlogopite and minor limonitic staining are present. Bedding is massive (Figure 8).

MINERALOGY:
Major: Dolomite
Minor: Phlogopite and quartz
Trace: Humite group(?)

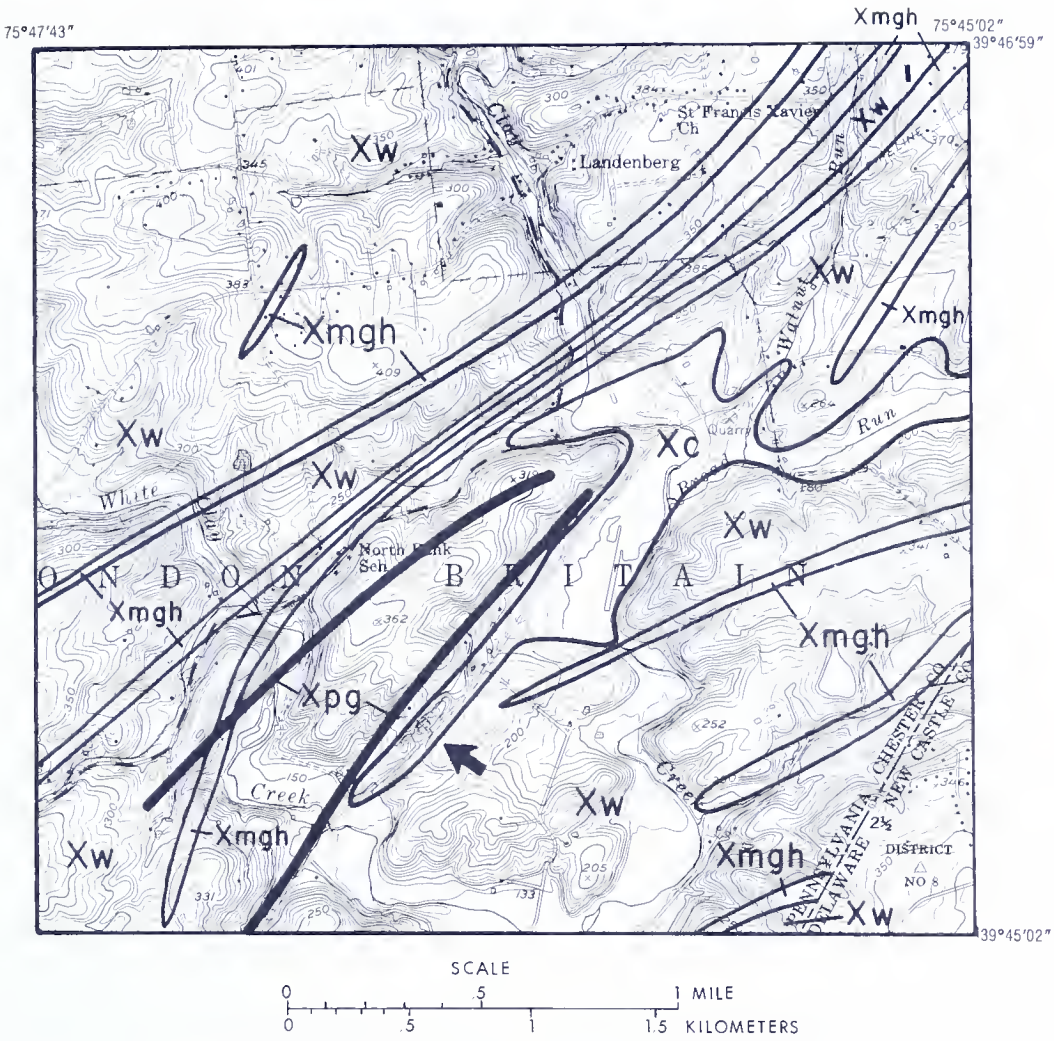
PHYSICAL TEST RESULTS:

	Dry brightness	*Whiteness*
Laboratory A	93.2	96.7
Laboratory B	89.9	81.1
Laboratory C	92.0	82.9

CHEMICAL TEST RESULTS:

CaO	= 31.8% ($CaCO_3$ = 56.8%)	Na_2O	= 230 ppm (value is near limit of detection)
MgO	= 23.0% ($MgCO_3$ = 48.1%)		
SiO_2	= 0.36%	K_2O	= <500 ppm
Fe_2O_3	= 0.15%	MnO	= 120 ppm
Al_2O_3	= 0.14%	TiO_2	= 88 ppm
		TOTAL	= 105.6%

CONCLUSIONS AND REMARKS: The brightness and whiteness values of the sampled interval indicate that the rocks might be used to produce whiting. The sampled interval from this location has the greatest whiteness values of any Cockeysville Marble tested, including the limestone sequences. The dolomite of this interval is very coarse grained, having individual crystals up to 0.25 in. (0.6 cm) in diameter. Allowing for analytical variances, the composition of the sample approaches that of pure dolomite and may have refractory and/or pharmaceutical uses.



EXPLANATION

Xpg — Pegmatite
Xmgh — Mafic gneiss, hornblende-bearing
Xw — Wissahickon Formation, oligoclase-mica schist
Xc — Cockeysville Marble

Figure 7. Geologic and location map of the abandoned quarry southwest of Landenberg, Chester County. Quarry is in the Cockeysville Marble, of probable Early Paleozoic age. Geology from Berg and Dodge (1981, p. 610).

This particular site probably could not be developed due to urbanization. However, other areas within the Landenberg district may have some development potential.

The quarry appears to be in a southwest-plunging anticline. Rocks in the

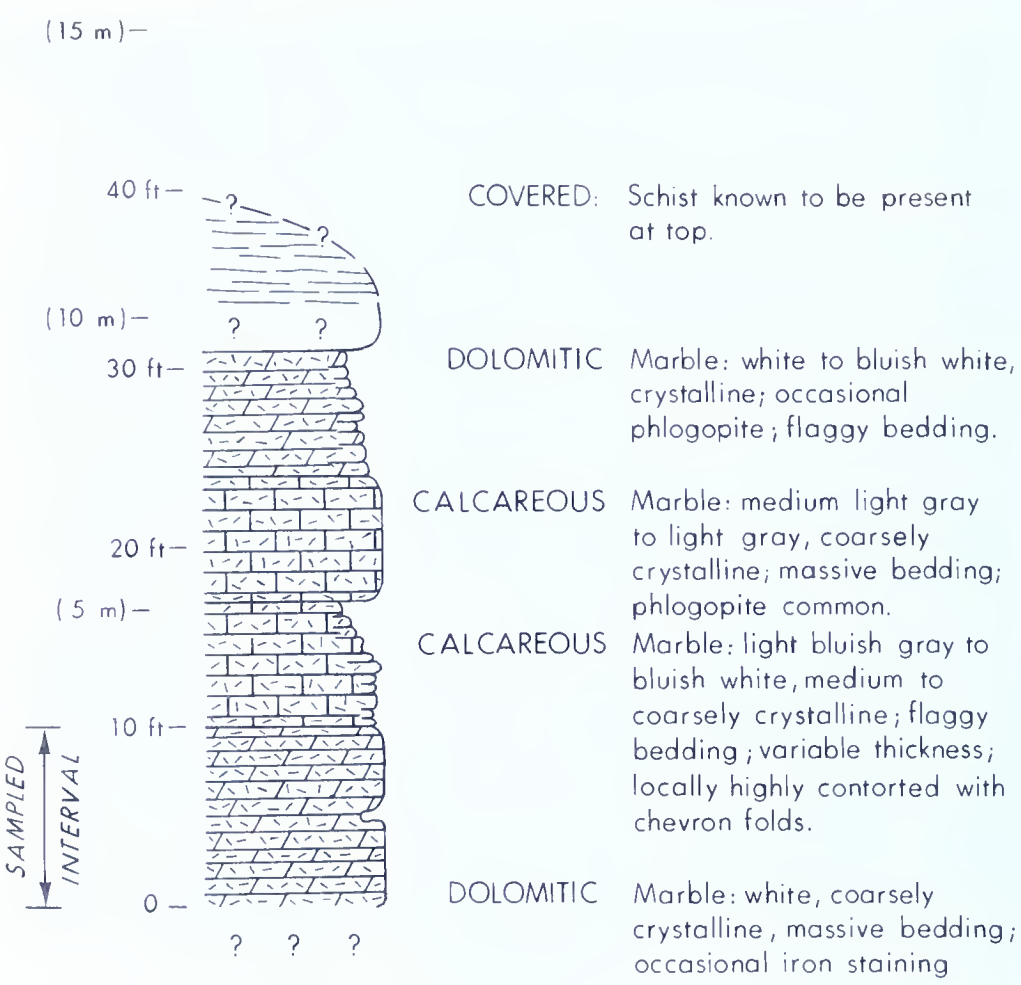

(15 m)—
40 ft—
(10 m)—
30 ft—
20 ft—
(5 m)—
10 ft—
0 —
SAMPLED INTERVAL
COVERED: Schist known to be present at top.
DOLOMITIC Marble: white to bluish white, crystalline; occasional phlogopite; flaggy bedding.
CALCAREOUS Marble: medium light gray to light gray, coarsely crystalline; massive bedding; phlogopite common.
CALCAREOUS Marble: light bluish gray to bluish white, medium to coarsely crystalline; flaggy bedding; variable thickness; locally highly contorted with chevron folds.
DOLOMITIC Marble: white, coarsely crystalline, massive bedding; occasional iron staining

Figure 8. Generalized stratigraphic section of the northwest face of the abandoned quarry southwest of Landenberg.

north face dip in a direction opposite to the dip of the rocks in the south face.

Other abandoned and overgrown quarries containing rocks that are less pure are located to the southwest and northeast.

ABANDONED LANDENBERG QUARRY

Sample 6–81

LOCATION: Same as for sample 7–81. See Figure 7.

TYPE OF EXPOSURE AND SAMPLE COLLECTED: Abandoned and partially overgrown pit about 40 feet (12 m) deep. The beds strike about

N65°E and dip approximately 33°SE. A composite sample, representing about 35 feet (10.5 m) of section, was taken of the badly weathered and stained exposure in the southeast corner of the pit; some intervals were covered.

STRATIGRAPHY: Mapped as Cockeysville Marble (Bascom and Stose, 1932), of probable Early Paleozoic age.

LITHOLOGY: Very light gray to white, coarsely crystalline dolomitic marble, which is friable, contains some phlogopite, and has limonitic staining. Little if any fresh rock was available.

MINERALOGY:
Major: Dolomite
Minor: Phlogopite and white prismatic tremolite
Trace: Limonite

PHYSICAL TEST RESULTS:

	Dry brightness	*Whiteness*
Laboratory A	90.7	95.4
Laboratory B	88.7	72.6
Laboratory C	89.6	73.1

CHEMICAL TEST RESULTS:

CaO	= 31.8% ($CaCO_3$ = 56.8%)	Na_2O	= 400 ppm
MgO	= 22.3% ($MgCO_3$ = 46.6%)	K_2O	= <500 ppm
SiO_2	= 1.4%	MnO	= 120 ppm
Fe_2O_3	= 0.16%	TiO_2	= 65 ppm
Al_2O_3	= 650 ppm	TOTAL	= 105.1%

CONCLUSIONS AND REMARKS: The brightness and whiteness values, particularly the latter, indicate that the rocks might produce marginally acceptable whiting. However, the sample was badly weathered and friable, and some improvement could be expected for a fresh face. The dolomite is quite pure and similar to that in sample 7-81. The source of the greater silica content may be quartz washed in from the nearby road or overlying schist. See sample 7-81 for additional comments.

ABANDONED PUSEY'S QUARRIES

Sample 2-81

LOCATION: Abandoned quarries northwest of Kennett Square about 1.9 miles (3.1 km) southwest of Willowdale on the west side of Mill Road, south

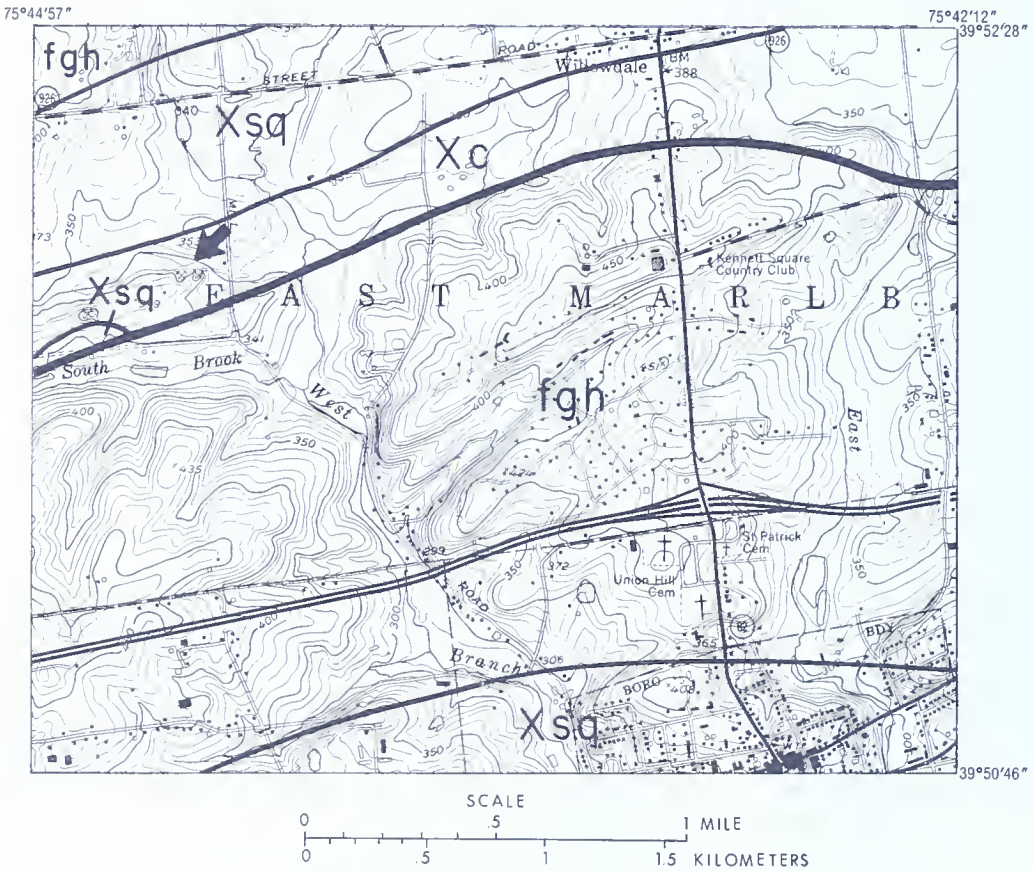
of Street Road and north of South Brook Creek (Figure 9).

Quadrangle: Kennett Square

Latitude: 39°51′54″N Longitude: 75°44′30″W

TYPE OF EXPOSURE AND SAMPLE COLLECTED: Abandoned and overgrown quarries. The attitude of bedding is unknown. Composite grab samples of float and/or outcrop at three very small, localized occurrences which, combined, may represent a 5-foot (1.5-m) stratigraphic interval. Marble was observed only in the westernmost of the two eastern pits, located about 500 feet (150 m) west of Mill Road (Figure 9).

STRATIGRAPHY: Mapped as Cockeysville Marble (Bascom and Stose, 1932), of probable Early Paleozoic age.



EXPLANATION

Xc —Cockeysville Marble
Xsq —Setters Quartzite
fgh —Felsic gneiss, hornblende-bearing

Figure 9. Geologic and location map of the abandoned Pusey's quarries, southwest of Willowdale, Chester County. Geology from Berg and Dodge (1981, p. 305).

LITHOLOGY: White to very light gray, coarsely crystalline, dolomitic marble.

MINERALOGY:
Major: Dolomite
Minor: None observed
Trace: Calcite, limonite, and phlogopite

PHYSICAL TEST RESULTS:

	Dry brightness	*Whiteness*
Laboratory A	91.7	95.9
Laboratory B	90.2	79.9
Laboratory C	91.1	80.4

CHEMICAL TEST RESULTS:

CaO	=	30.8% ($CaCO_3$ = 54.1%)	Na_2O	=	<100 ppm
MgO	=	22.6% ($MgCO_3$ = 47.2%)	K_2O	=	<500 ppm
SiO_2	=	<90 ppm	MnO	=	140 ppm
Fe_2O_3	=	0.16%	TiO_2	=	37 ppm
Al_2O_3	=	330 ppm	TOTAL	=	101.6%

CONCLUSIONS AND REMARKS: The brightness and whiteness values for the sampled interval indicate that the rocks might have some potential for use as a whiting product. The chemical analysis for this sample shows the rocks to be pure dolomite which may have potential for refractory and pharmaceutical uses if a minable thickness could be verified.

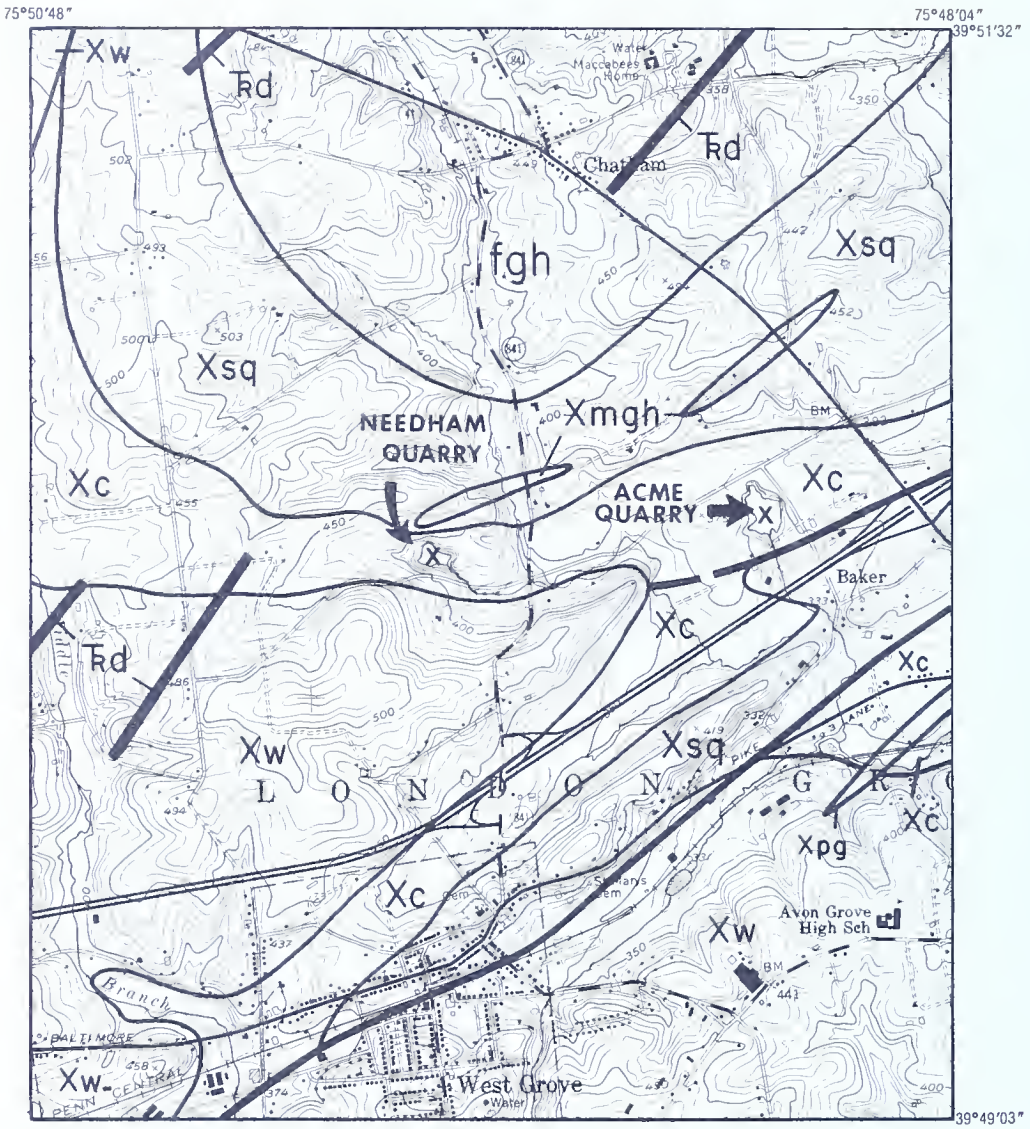
Gordon (1922) reports the occurrence of calcite, dolomite, quartz, microcline, tremolite, tourmaline, muscovite, rutile, pyrite, and graphite at these pits. The pits are estimated to be about 25 feet (8 m) deep; about half of this depth appears to be in the overlying schist. The quarries are located on and surrounded by country estates which probably are not available for quarry development. There are several nearby farm sites that may have development potential.

ABANDONED ACME-BAKER QUARRY

Sample 9-81

LOCATION: Abandoned quarry about 1,500 feet (460 m) northwest of Baker, 2,000 feet (600 m) west of the intersection of U.S. Route 1 and Pa. Route 41, and about 1.1 mile (1.8 km) southeast of Chatham, in London Grove Township, Chester County (Figure 10).

Quadrangle: West Grove
Latitude: 39°50′24″N Longitude: 75°40′39″W



EXPLANATION

- Trd — Diabase
- Xpg — Pegmatite
- Xmgh — Mafic gneiss, hornblende-bearing
- Xw — Wissahickon Formation, oligoclase-mica schist
- Xc — Cockeysville Marble
- Xsq — Setters Quartzite
- fgh — Felsic gneiss, hornblende-bearing

Figure 10. Geologic and location map of the abandoned Needham quarry and the abandoned Acme-Baker quarry, northwest of Baker, Chester County. Geology from Berg and Dodge (1981, p. 610).

TYPE OF EXPOSURE AND SAMPLE COLLECTED: Abandoned, overgrown, and water-filled quarry surrounded by waste dumps from a dimension-stone industry. The attitude of the beds is subhorizontal, and they dip gently to the south. A high-grade composite sample was taken of a waste dump in the northwest corner of the quarry.

STRATIGRAPHY: Mapped as Cockeysville Marble (Bliss and Jonas, 1917; Bascom and Stose, 1932), of probable Early Paleozoic age.

LITHOLOGY: Very light gray to white, coarsely crystalline, dolomitic and calcareous marble containing some faint laminations and banding, common phlogopite, and some limonite.

MINERALOGY:

Major: Calcite
Minor: Phlogopite (minor to trace)
Trace: Pyrite and tremolite (X-ray defraction)

PHYSICAL TEST RESULTS:

	Dry brightness	*Whiteness*
Laboratory A	90.6	95.3
Laboratory B	89.6	79.5
Laboratory C	89.9	79.7

CHEMICAL TEST RESULTS:

CaO	= 31.8% ($CaCO_3$ = 56.8%)	Na_2O	= 170 ppm
MgO	= 18.0% ($MgCO_3$ = 37.7%)	K_2O	= 0.20%
SiO_2	= 2.5%	MnO	= 70 ppm
Fe_2O_3	= 0.20%	TiO_2	= 170 ppm
Al_2O_3	= 0.35%	TOTAL	= 97.8%

CONCLUSIONS AND REMARKS: The brightness and whiteness values for the sampled interval indicate that the rocks might be used to produce whiting. This quarry has previously been referred to in the literature as the Acme quarry operated by the Pennsylvania Marble and Granite Company. Bliss and Jonas (1917) list the following chemical analysis for the quarry rocks:

$CaCO_3$	57.125
$MgCO_3$	12.498
SiO_2	1.235
$Fe_2O_3 + Al_2O_3$	3.770
$H_2O + CO_2$	25.372
	100.000

The following section, described by Bascom and Stose (1932, p. 4) for the quarry, suggests that there may be at least a 60-foot (20-m) stratigraphic sequence of minable carbonate rocks suitable for use as whiting.

	Feet	
Phlogopitic gray limestone, referred to by the quarrymen as "Avondale limestone"	10–30	[3–9 m]
Tremolite-phlogopite-quartz rock, locally called "bastard granite"	16–18	[5–6 m]
Very pure white granular limestone, locally called "fish-egg limestone"	10	[3 m]
Even-grained white magnesian marble, called "dolomite"	50	[15 m]

In addition, they reported that this quarry was originally opened to supply lime kilns. Miller (1934) observed eight old lime kilns near the quarry. The decline of the lime industry initiated a drilling program for marble. As a result of diamond drilling, white dolomitic marble of good quality, low absorption, and high resistance to staining was identified at a depth of about 50 to 70 feet (15 to 20 m) (Bascom and Stose, 1932). The dolomitic marble was reported to be quarried to a depth of 50 feet (15 m), which suggests that the quarry was developed to about 100 feet (30 m) below ground level. Miller (1934) stated that the quarry was worked to a depth of 150 feet (45 m). It is believed that this quarry was last worked in 1919 for dimension stone. There was an associated mill, where the marble was sawed and shaped for market. The Southeast Chester County Authority is the owner listed on trespass notices.

ABANDONED ACME–BAKER QUARRY

Sample 10–81

LOCATION: Same as for sample 9–81. See Figure 10.

TYPE OF EXPOSURE AND SAMPLE COLLECTED: Abandoned, overgrown, and water-filled quarry. The attitude of the beds was not measured, but they were observed to dip gently to the south. A composite sample was taken of the ledge above water level in the northeastern portion of the quarry. The stratigraphic interval sampled was about 3 feet (1 m) thick.

STRATIGRAPHY: Mapped as Cockeysville Marble (Bliss and Jonas, 1917; Bascom and Stose, 1932), of probable Early Paleozoic age.

LITHOLOGY: Light-gray to medium-light-gray, coarsely crystalline, calcareous marble, containing distinctly banded, abundant phlogopite, minor quartz and pyrite, and rare brown tourmaline crystals.

MINERALOGY:
Major: Calcite
Minor: Phlogopite and quartz
Trace: Pyrite and rare dravite tourmaline

PHYSICAL TEST RESULTS:

	Dry brightness	*Whiteness*
Laboratory A	84.7	92.2
Laboratory B	83.5	76.6
Laboratory C	84.3	77.3

CHEMICAL TEST RESULTS:

CaO	= 47.3% ($CaCO_3$ = 84.4%)	Na_2O	= 380 ppm
MgO	= 4.5% ($MgCO_3$ = 9.4%)	K_2O	= 0.36%
SiO_2	= 4.8%	MnO	= 49 ppm
Fe_2O_3	= 0.29%	TiO_2	= 380 ppm
Al_2O_3	= 0.81%	TOTAL	= 100.1%

CONCLUSIONS AND REMARKS: The whiteness and brightness values for this sample indicate that the rocks probably could not produce whiting. Although the whiteness and brightness values are rather low, they are considerably higher than would have been expected from the eyeball ranking (Tables 1 and 2). Measured brightness and whiteness values for the sample are below acceptable levels for whiting products, but blending of these darker rocks with whiter calcareous or dolomitic marble could possibly be a means to extend reserves and eliminate some waste rock.

ABANDONED NEEDHAM QUARRY

Sample 8–81

LOCATION: Abandoned pit about 1 mile (1.6 km) north of West Grove, about 1 mile (1.6 km) south of Chatham, and about 1,300 feet (400 m) west of Pa. Route 841, in London Grove Township, Chester County (Figure 10).

Quadrangle: West Grove
Latitude: 39°50′20″N Longitude: 75°49′38″W

TYPE OF EXPOSURE AND SAMPLE COLLECTED: Abandoned, overgrown, and water-filled quarry which has minor float(?) or outcrop(?) near water level. The bedding attitude is unknown. A composite sample was taken from two sources (outcrop and/or float) on the north slope of the pit near water level.

STRATIGRAPHY: Mapped as Cockeysville Marble (Bascom and Stose, 1932), of probable Early Paleozoic age.

LITHOLOGY: White to bluish-white, coarsely crystalline, calcareous marble containing some pyrite.

MINERALOGY:
Major: Calcite
Minor: None observed
Trace: Pyrite and phlogopite

PHYSICAL TEST RESULTS:

	Dry brightness	*Whiteness*
Laboratory A	90.8	95.5
Laboratory B	89.8	76.5
Laboratory C	90.3	77.1

CHEMICAL TEST RESULTS:

CaO	= 42.8% ($CaCO_3$ = 76.4%)	Na_2O	= <100 ppm
MgO	= 9.9% ($MgCO_3$ = 20.7%)	K_2O	= 0.29%
SiO_2	= 3.6%	MnO	= 83 ppm
Fe_2O_3	= 0.24%	TiO_2	= 320 ppm
Al_2O_3	= 0.68%	TOTAL	= 102.0%

CONCLUSIONS AND REMARKS: The brightness values of this sample indicate that the rocks could make a whiting product. However, the whiteness values of the rocks are marginal for whiting. This is the only truly white calcareous marble tested from the Cockeysville. The bed thickness is unknown, but the sample may represent the rather persistent 10-foot- (3-m-) thick "fish-egg limestone" referred to by Bascom and Stose (1932). Generally, soil and colluvium cover the faces and slopes around the pit. Bliss and Jonas (1917) stated that there are no natural outcrops of the "fish-egg limestone," and that it can best be delineated by a residual red clay soil. They also reported that the strike ranges between N60°E and N70°E, and the dip is generally southeast at about 20° to 25° for the Avondale-West Grove area.

ABANDONED POORHOUSE QUARRY

Sample 1–81

LOCATION: Abandoned quarry northeast of Embreeville, about 3,800 feet (1,150 m) southeast of the north entrance to the Embreeville State Hospital and about 4,500 feet (1,400 m) north of Glenhall, in West Bradford Township, Chester County (Figure 11).

Quadrangle: Unionville
Latitude: 39°56′34″N Longitude: 75°42′56″W

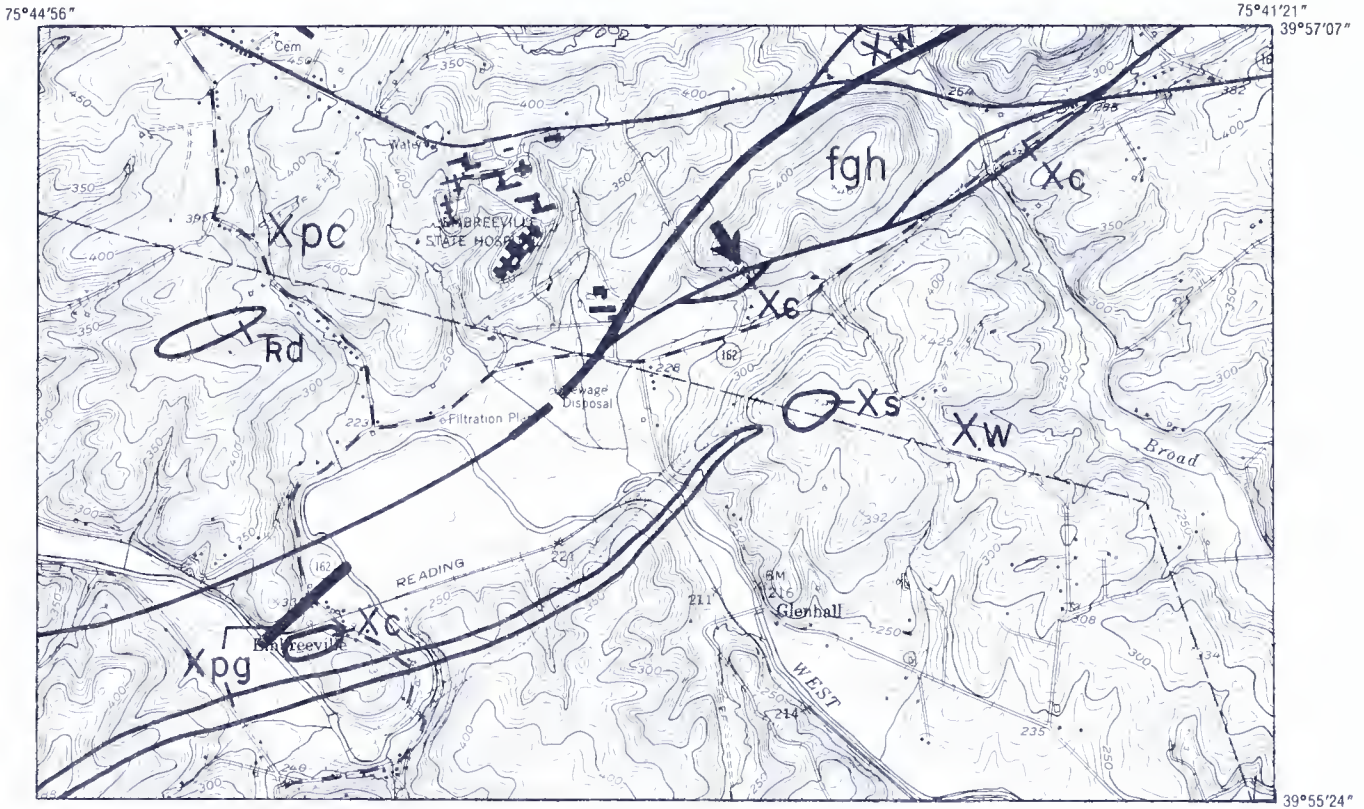


Figure 11. Geologic and location map of the abandoned Poorhouse quarry, Embreeville, Chester County. Geology revised from Berg and Dodge (1981, p. 588).

TYPE OF EXPOSURE AND SAMPLE COLLECTED: Abandoned and overgrown quarry; hillside-type pit having one level of development. The attitude of the beds is subhorizontal, and they dip slightly to the south. A composite sample was taken of the exposed eastern face, representing about 40 feet (12 m) of stratigraphic section (Figure 12).

STRATIGRAPHY: Mapped as Cockeysville Marble (Bascom and Stose, 1932), of probable Early Paleozoic age.

LITHOLOGY: White to very light gray, coarsely crystalline, dolomitic marble containing some phlogopite and quartz.

MINERALOGY:

Major: Dolomite
Minor: Phlogopite and quartz (as fracture fillings and lenses)
Trace: Pyrite, microcline, rutile, and calcite

PHYSICAL TEST RESULTS:

	Dry brightness	*Whiteness*
Laboratory A	89.7	94.8
Laboratory B	89.0	75.3
Laboratory C	89.3	75.1

CHEMICAL TEST RESULTS:

CaO	= 30.3% ($CaCO_3$ = 54.1%)	Na_2O	= <100 ppm
MgO	= 22.0% ($MgCO_3$ = 46.0%)	K_2O	= 610 ppm (value is near limit of detection)
SiO_2	= 1.0%		
Fe_2O_3	= 0.22%	MnO	= 150 ppm
Al_2O_3	= 0.32%	TiO_2	= 200 ppm
		TOTAL	= 101.7%

CONCLUSIONS AND REMARKS: The brightness and the whiteness values for the sampled interval indicate that the rocks might produce a marginal whiting product. The chemistry of the dolomitic marble is fairly pure, and the rocks could be a potential source for pharmaceutical and refractory dolomite. Gordon (1922) observed quartz crystals (4 × 1-1/2 inches, or 10 × 4 cm), calcite scalenohedra, dolomite crystals, microcline crystals, tremolite, muscovite, phlogopite, zoisite(?), chlorite, rutile crystals up to an inch (2.5 cm) in length, and pyrite.

A. R. Geyer (personal communication, 1981) reported that two water wells drilled with a cable tool rig in 1956 penetrated about 170 feet (50 m) of Cockeysville section. The descriptive logs are presented in Figures 13 and 14. The exact locations of these wells are questionable. However, well 1 is believed to have been drilled approximately 900 feet (270 m) southeast of the Embreeville State Hospital filtration plant. Well 2 is believed to have been drilled near the east side of the southeast entrance road to the hospital.

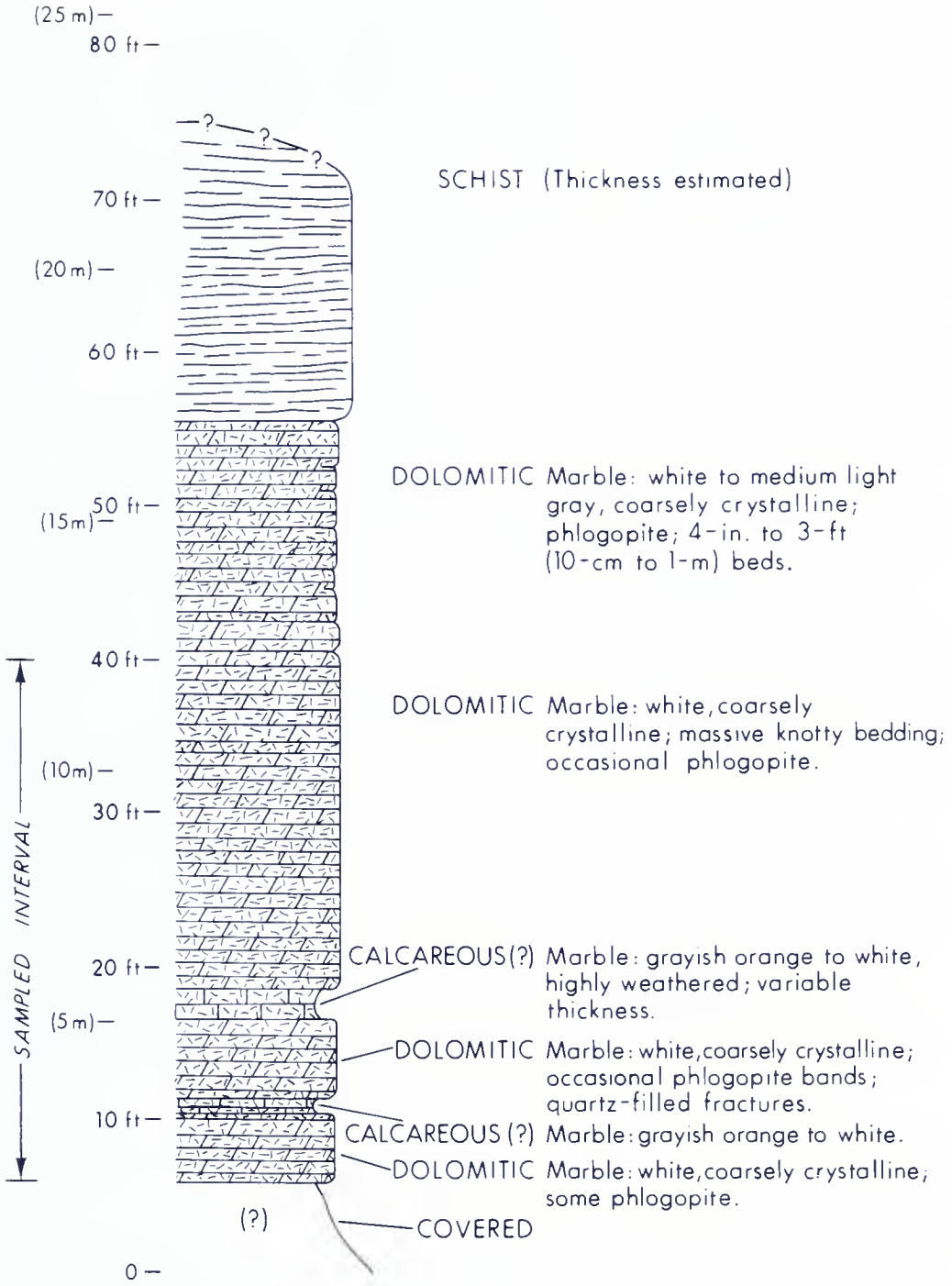


Figure 12. Generalized stratigraphic section of the eastern face of the abandoned Poorhouse quarry.

Well 2 appears to have penetrated 90 feet (27 m) of very light gray to white marble (Figure 14). The topography and data interpreted from both wells suggest that portions of the alluvial valley of the West Branch of Brandywine Creek, south of the State Hospital, may be underlain by Cockeysville Marble.

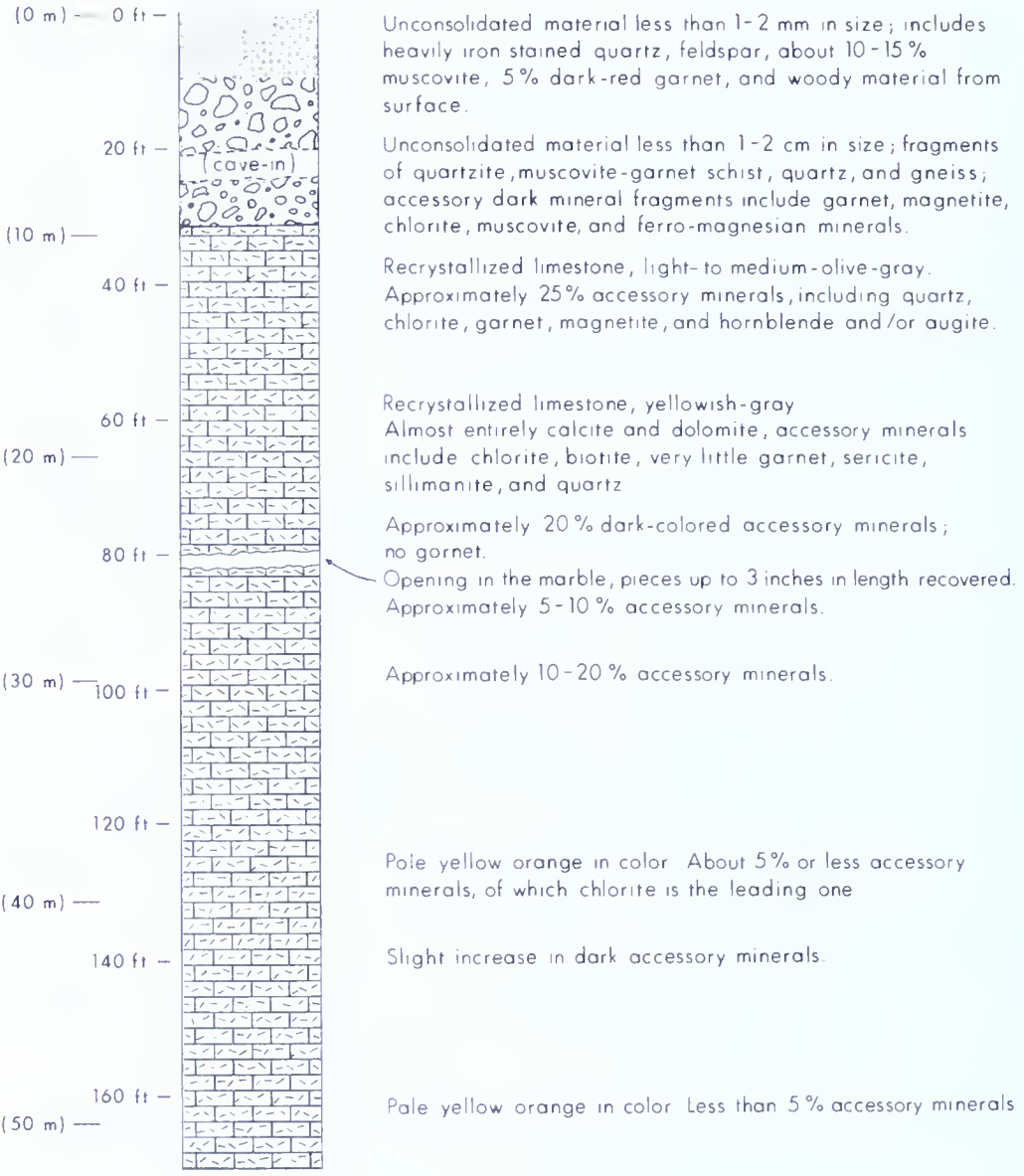

(0 m)
0 ft
20 ft
(cave-in)
(10 m)
40 ft
60 ft
(20 m)
80 ft
(30 m)
100 ft
120 ft
(40 m)
140 ft
160 ft
(50 m)
Unconsolidated material less than 1-2 mm in size; includes heavily iron stained quartz, feldspar, about 10-15% muscovite, 5% dark-red garnet, and woody material from surface.
Unconsolidated material less than 1-2 cm in size; fragments of quartzite, muscovite-garnet schist, quartz, and gneiss; accessory dark mineral fragments include garnet, magnetite, chlorite, muscovite, and ferro-magnesian minerals.
Recrystallized limestone, light- to medium-olive-gray. Approximately 25% accessory minerals, including quartz, chlorite, garnet, magnetite, and hornblende and/or augite.
Recrystallized limestone, yellowish-gray
Almost entirely calcite and dolomite, accessory minerals include chlorite, biotite, very little garnet, sericite, sillimanite, and quartz
Approximately 20% dark-colored accessory minerals; no gornet.
Opening in the marble, pieces up to 3 inches in length recovered. Approximately 5-10% accessory minerals.
Approximately 10-20% accessory minerals.
Pale yellow orange in color About 5% or less accessory minerals, of which chlorite is the leading one
Slight increase in dark accessory minerals.
Pale yellow orange in color Less than 5% accessory minerals

Figure 13. Descriptive log of Embreeville State Hospital water well 1.

The potential for site development is presently unknown. However, if water inflow can be controlled, underground mining might be possible at some of the higher elevations. Several large farms appear to be underlain by the Cockeysville in this area.

CUMBERLAND COUNTY

Investigations in Cumberland County were confined to the Ordovician St. Paul Group at one locality, the Hempt Brothers quarry. The carbonate

(0 m)
0 ft
20 ft
(10 m)
40 ft
60 ft
(20 m)
80 ft
(30 m)
100 ft
120 ft
(40 m)
140 ft
160 ft
(50 m)
Uncansalidated material; chips af quartz, schist etc , very little calcite
Recrystallized limestane, maderate-yellawish-brawn; >5% accessory minerals, including quartz, sericite, and ferra-magnesian minerals.
Recrystallized limestane, maderate-yellawish-brawn, >5% accessory minerals, including sericite, biatite, ferra-magnesian minerals, magnetite, quartz, and chlarite
Recrystallized limestane, light-yellawish-brawn; >5% accessary minerals, including chlarite and garnet
Recrystallized limestane, maderate-yellawish-brawn; 5-10% accessary minerals, including magnetite, garnet, quartz, and sericite
Recrystallized limestane with interbeds af schistase material, medium-dark-gray; accessary minerals include magnetite, garnet, pyrite, sericite, muscovite, and biatite
Recrystallized limestane, light-grayish-yellawish-brawn, appraximately 10% accessary minerals, including muscovite, biatite, magnetite, chlarite, and quartz.
Recrystallized limestane, very light gray
Recrystallized limestane, very light gray, >5% accessary minerals, including muscavite, chlarite, quartz, and garnet
Recrystallized limestane; water reparted
Recrystollized limestane, white, >1% accessary minerals, including chlarite, garnet, and muscavite
Recrystallized limestane, white, less accessory minerals than in averlying 50 feet

Figure 14. Descriptive log of Embreeville State Hospital water well 2.

sequence exposed at the quarry is part of the South Mountain anticlinorium and is located about 1,000 feet (300 m) north of the Yellow Breeches thrust sheet. This low-angle thrust marks a major structural boundary between the overlying allochthonous Ordovician rocks to the south and the subjacent autochthonous Cambro-Ordovician carbonate rocks of the South Mountain anticlinorium to the north (Root and MacLachlan, 1978).

The St. Paul Group generally consists of light-gray, thick-bedded, high-calcium, micritic limestone. It may reach a total thickness of about 900 feet (275 m) in the study area (Root, 1977).

HEMPT BROTHERS QUARRY

Sample 18–81

LOCATION: Active quarry north of Yellow Breeches Creek about 1.1 mile (1.8 km) east of the State Correctional Institution, due east of Lisburn Road, and 200 feet (60 m) south of Eberlys Mill, in Lower Allen Township, Cumberland County (Figure 15).

Quadrangle: Lemoyne
Latitude: 40°13′14″N Longitude: 76°54′20″W

TYPE OF EXPOSURE AND SAMPLE COLLECTED: Active open pit which has multiple levels of development. The strike of the beds is generally about N55°E, and the dip is about 30°SE. A composite sample, representing about 25 feet (8 m) of stratigraphic thickness, was taken from the western face of the lowermost level (Figure 16).

STRATIGRAPHY: Mapped as the Ordovician St. Paul Group (Root, 1977).

LITHOLOGY: Light-gray to white, very fine grained, sheared calcareous marble. Some faint laminae and some calcite crystals are present. Fractures are conchoidal. The white beds appear to be lensoidal in nature.

MINERALOGY:
Major: Calcite
Minor: None observed
Trace: Dolomite

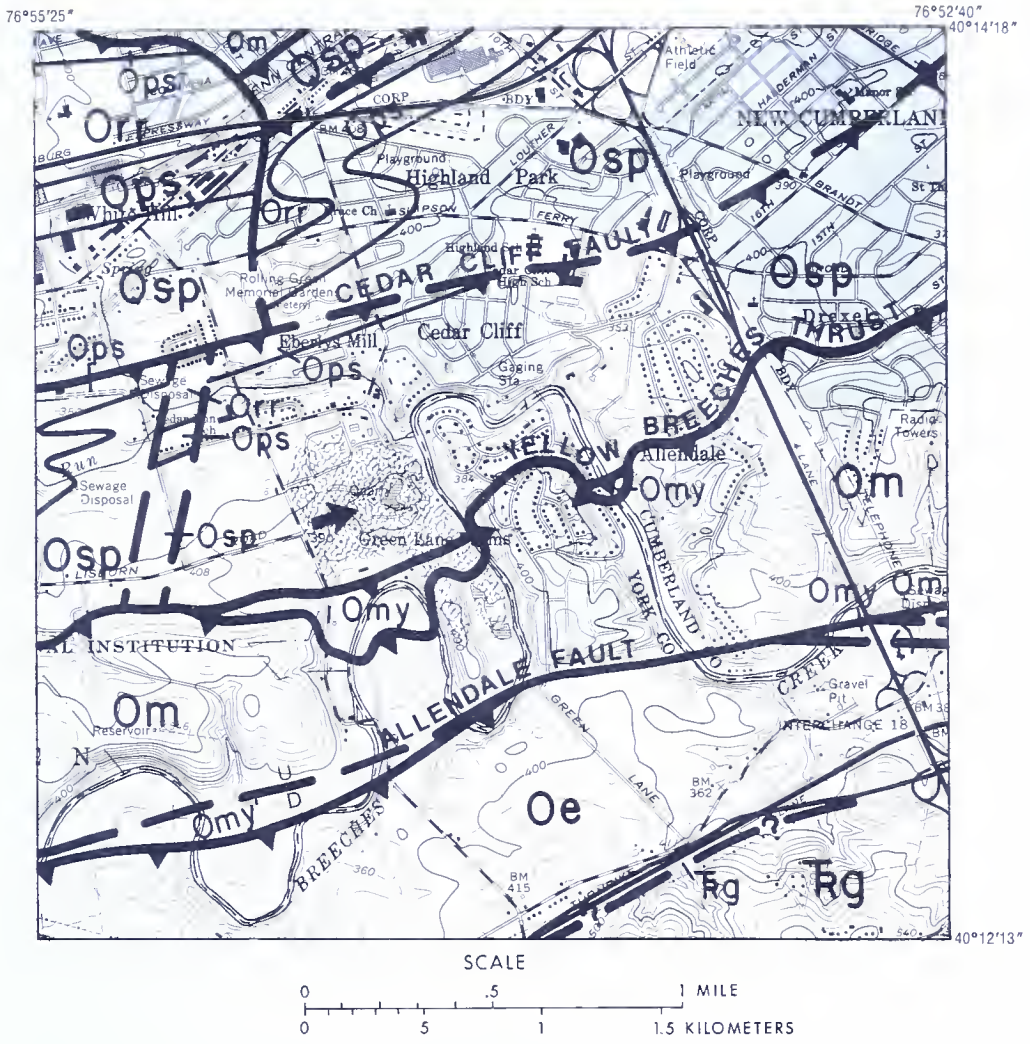
PHYSICAL TEST RESULTS:

	Dry brightness	*Whiteness*
Laboratory A	91.2	95.6
Laboratory B	89.8	85.4
Laboratory C	90.5	86.0

CHEMICAL TEST RESULTS:

CaO	= 56.7% ($CaCO_3$ = 101.2%)	Na_2O	= 130 ppm (value is near the limit of detection)
MgO	= 0.85% ($MgCO_3$ = 1.8%)	K_2O	= <500 ppm
SiO_2	= <90 ppm	MnO	= 71 ppm
Fe_2O_3	= 99 ppm	TiO_2	= 40 ppm
Al_2O_3	= <100 ppm	TOTAL	= 103.1%

CONCLUSIONS AND REMARKS: The brightness and whiteness values for the sampled interval indicate that the rocks might be used to produce



EXPLANATION

Trg — Gettysburg Formation, shale and sandstone
Om — Martinsburg Formation, shale
Omy — Myerstown Formation, limestone
Osp — St. Paul Group, limestone
Ops — Pinesburg Station Formation, dolomite
Orr — Rockdale Run Formation, limestone
Oe — Epler Formation, dolomite and limestone

Figure 15. Geologic and location map of the Hempt Brothers quarry, Cumberland County. Geology from Root (1977).

whiting. The rocks sampled have an exceedingly pure chemistry; the SiO_2, Fe_2O_3, and Al_2O_3 contents combined do not exceed 300 ppm. This nearly pure calcareous marble could have many other potential uses such as a sweetener for Portland cement, as lime, as a flux, and in pharmaceuticals.

In contrast to his thin, apparently pure sampled interval, Root (1977) reported 20 chemical analyses of random samples provided by the operators (Root, 1977, Table 7, p. 68). Results and interpretations are somewhat sus-

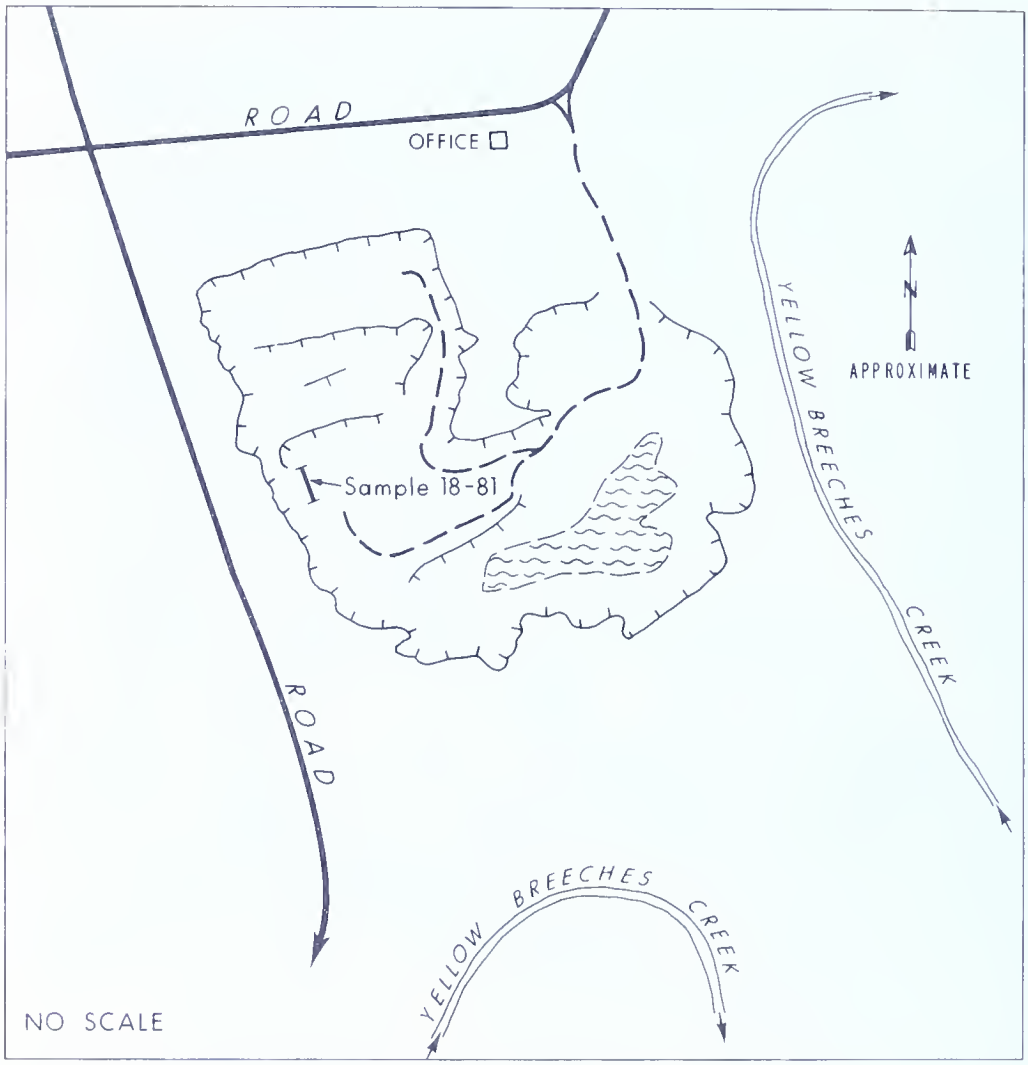


Figure 16. Sketch map of sample locations, Hempt Brothers quarry.

pect because of unknown sampling and analytical techniques. However, Root (1977) stated that these analyses are typical of the medial St. Paul in this area and concluded that it would be difficult to produce a high-calcium product. Obviously, selective mining was not considered. Indeed some of the darker beds in the quarry are dolomitic and highly argillaceous, which could influence random chemical analyses from a stockpile.

Miller (1934) reported that this quarry was opened in 1925 and also reported observing some fluorite there. The carbonates sampled have a conchoidal fracture and sheared appearance. There appear to be rapid facies changes along strike. Boudinage structures, recumbent isoclinal structures, and imbricate or shingle zones have been observed in this quarry. As can be seen from the geologic map (Figure 15), the area is structurally complex. The proximity of the Hempt quarry to allochthonous rocks has apparently left its structural imprint on these once-subjacent autochthonous carbon-

ates, as evidence mentioned above suggests. Hence, the bleached(?) and chemically pure limestone may be difficult to selectively mine if its occurrence is controlled by structure rather than stratigraphy.

The possibility of other quarries being developed in the immediate vicinity is remote due to urbanization. Whether the St. Paul Group has similar chemical and physical characteristics elsewhere is unknown.

OTHER COUNTIES

Some additional sites investigated, sampled, tested, and considered unacceptable as carbonate whiting sources are listed in Table 7 in the appendix. These include samples collected from carbonate sequences in Adams, Chester, Franklin, Lancaster, and York Counties (Table 8). The chemical analyses for these samples may, however, be of value in determining other potential uses.

BENEFICIATION TEST RESULTS

Visually there is an unmistakable contrast in whiteness between the magnetic and nonmagnetic splits of the samples chosen for beneficiation. Due to poor reproducibility of brightness and whiteness measurements between batches of samples, a comparative eyeball ranking of beneficiated samples is listed in Table 5.

Unbeneficiated sample 9–81 was included for visual comparison because it meets minimal commercial whiteness and brightness values. That is, samples having higher whiteness and brightness than sample 9–81 have commercial potential, and those having lower whiteness and brightness probably do not.

Beneficiation significantly increased the ranking of samples 1–81 and 9–81 from below to above apparent commercial grade. These two samples, coarsely crystalline Cockeysville dolomites, improved because phlogopite and gray dolomite were removed.

Table 6 lists the major, minor, and trace mineralogy of the magnetic tailings removed from the beneficiated samples.

CONCLUSIONS

FAVORABLE STRATIGRAPHIC UNITS:

(1) The middle limestone unit of the Cambrian Kinzers Formation in the strike belt between Hanover and York and probably eastward to Wrightsville appears to be a significant exploration target for the pulverized-limestone industry. Additional work could be done east of the Susquehanna River on the unit to establish the strike length of the potential whiting resource.

Table 5. *Results of Beneficiation Tests Using Frantz Magnetic Separator*

County	Name and location of quarry (Geologic unit)	Sample no.	Ranking of whiteness of seven beneficiated samples[1,2]	Tint by eye[2]	Magnetic fraction (percent)[3]
York	White Pigment Corp., West York (Kinzers Formation)	17–81	1	—	5
Adams	Bethlehem Mines Corp., Hanover (Kinzers Formation)	13–81	2	Gray	19
Chester	Acme-Baker quarry, Baker (Cockeysville Marble)	9–81	3	Greenish-gray	19
	Poorhouse quarry, Embreeville (Cockeysville Marble)	1–81	4	Green	21
	Acme-Baker quarry, Baker (Cockeysville Marble)	9–81	5	Beige	Unbeneficiated
York	Laucks quarry, West York (Kinzers Formation)	16–81	6	Pink	16
Chester	Landenberg quarry, Landenberg (Cockeysville Marble)	6–81	7	Buff-yellow	11
York	Gardner quarry, York Springs (Tomstown(?) Formation)	3–81	8	Gray	26

[1] All brightness and whiteness values were determined from samples ground so that 100 percent of the material passed the 80-mesh sieve.

[2] Data are based on visual examination of the samples by three Survey geologists under indoor fluorescent lighting.

[3] Weight percent of magnetic tailings.

(2) The Lower Paleozoic(?) Cockeysville Marble of southeastern Pennsylvania appears to have dolomitic and calcareous marble sequences that might be suitable as a raw material for whiting.

(3) The Ordovician St. Paul Group of limestones, particularly in the Harrisburg area, needs further study to determine if minable sequences of white marble are present.

FAVORABLE GEOGRAPHIC LOCATIONS:

(1) Adams and York Counties are primary target areas for exploring for Cambrian Kinzers Formation limestones. Obviously, farmlands under-

Table 6. *Mineralogy of Magnetic Tailings*

County	Name and location of quarry	Sample no.	Mineralogy		
			Major	Minor	Trace
York	White Pigment Corp., West York	17–81	Calcite	Dolomite	Quartz, pyrite, mica
Adams	Bethlehem Mines Corp., Hanover	13–81	Calcite	None	Hematitic staining, limonite-pyrite, dolomite
Chester	Acme-Baker quarry, Baker	9–81	Dolomite	Phlogopite, calcite	Pyrite with limonitic coating, tremolite
	Poorhouse quarry, Embreeville	1–81	Dolomite	Phlogopite	Pyrite with limonitic coating, calcite
York	Laucks quarry, West York	16–81	Calcite	Dolomite, hematitic staining	None
Chester	Landenberg quarry, Landenberg	6–81	Dolomite	Calcite, phlogopite	Pyrite with limonitic coating, tremolite
York	Gardner quarry, York Springs	3–81	Gray calcite	None	Dolomite, pyrite

lain by the middle Kinzers unit are potentially the most desirable initial prospects. Careful and systematic attention would have to be given to obtaining zoning variances in most areas. Underground mining considerations might be a positive factor in obtaining zoning variances near populated areas such as Hanover, Spring Grove, York, and Wrightsville. The other alternative is to seek operating quarries that are in, or could be developed in, favorable horizons of the middle Kinzers limestone. Active quarries that are in the middle limestone include Bethlehem Mines Corporation, Hanover; Thomasville Stone and Lime Company, Thomasville; National Gypsum Company, West York; White Pigment Corporation, West York; York Stone and Supply Company, West York; and Medusa Cement Company, West York.

(2) Chester County in southeastern Pennsylvania is a favorable target area for exploring for the Lower Paleozoic(?) Cockeysville Marble. The five main outcrop belts or districts (Embreeville, Kennett Square, Avondale-West Grove, Landenberg, and Doe Run) all include some agricultural lands, even though they are close to the expanding greater Philadelphia metropolitan area. Some townships in these areas have relatively few zoning restrictions due to the mushroom farming industry. Underground mining could play a significant role in establishing a mining operation in this area. If groundwater problems are not too

formidable, the established mushroom industry might enthusiastically welcome the underground space created.

(3) The Ordovician St. Paul Group may have potential as a whiting source in Cumberland and Dauphin Counties. The one occurrence favorably tested in Cumberland County (Hempt Brothers quarry) is a sheared-looking limestone that may be the result of local thrust faulting associated with Alpine-type nappe structures.

WHITENESS AND BRIGHTNESS VALUES OF MOST ANALYZED SAMPLES MIGHT BE INCREASED BY THE FOLLOWING:

(1) Fine grinding so that 97 percent of the material passes the 325-mesh (0.044-mm) sieve.
(2) Obtaining fresh outcrop samples that would compare to developed quarry faces or mine faces.
(3) Beneficiation of the Cockeysville Marble to remove phlogopite, gray dolomite, and pyrite.
(4) Beneficiation of the Kinzers marble lithofacies to remove gray dolomite.

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APPENDIX

Table 7. *Test Results—Brightness, Whiteness, and Chemical Analyses for All Samples Tested*

County	Sample no.	DRY BRIGHTNESS Lab A	Lab B	Lab C	WHITENESS Lab A	Lab B	Lab C	CHEMISTRY (inductively coupled plasma analysis)[1] CaO (%)	MgO (%)	SiO_2	Al_2O_3	Fe_2O_3	Na_2O	K_2O	MnO	TiO_2	LOI (%)	Total (%)
Adams	3–81	81.9	79.6	81.2	90.6	65.8	66.4	52.7	1.8	0.95%	900	910	*290	<500	110	95	43.4	99.1
Adams	12–81	90.8	89.5	90.3	95.4	84.4	85.4	54.5	1.1	<90	330	270	*220	<500	72	45	42.6	98.4
Adams	13–81	91.6	90.1	91.0	95.8	81.8	82.7	55.0	0.55	<90	540	130	*190	<500	87	53	43.6	99.3
Adams	14–81	84.7	82.6	83.8	92.2	65.7	67.1	53.7	1.8	530	0.14%	0.12%	*280	<500	130	61	43.2	99.1
Adams	15–81	89.5	88.3	88.9	94.8	77.6	77.9	54.2	1.4	1.00%	630	330	*210	<500	55	60	43.8	100.6
Chester	1–81	89.7	89.0	89.3	94.8	75.3	75.1	30.3	22.0	1.00%	0.32%	0.22%	<100	*610	150	200	45.9	99.8
Chester	2–81	91.7	90.2	91.1	95.9	79.9	80.4	30.8	22.6	<90	330	0.16%	<100	<500	140	37	46.9	100.6
Chester	6–81	90.7	88.7	89.6	95.4	72.6	73.1	31.8	22.3	1.4%	650	0.16%	400	<500	120	65	45.5	101.3
Chester	7–81	93.2	89.9	92.0	96.7	81.1	82.9	31.8	23.0	0.36%	0.14%	0.15%	*230	<500	120	88	46.6	102.1
Chester	8–81	90.8	89.8	90.3	95.5	76.5	77.1	42.8	9.9	3.6%	0.68%	0.24%	<100	0.29%	83	320	43.5	101.1
Chester	9–81	90.6	89.6	89.9	95.3	79.5	79.7	31.8	18.0	2.5%	0.35%	0.20%	170	0.20%	70	170	44.4	97.5
Chester	10–81	84.7	83.5	84.3	92.2	76.6	77.3	47.3	4.5	4.8%	0.81%	0.29%	380	0.36%	49	380	41.3	99.4
Cumberland	18–81	91.2	89.8	90.5	95.6	85.4	86.0	56.7	0.85	<90	<100	99	*130	<500	71	40	43.0	100.7
Franklin	4–81	75.7	72.9	75.1	87.2	60.7	61.7	46.7	5.1	4.3%	0.77%	0.23%	450	0.32%	56	380	42.2	99.7
Franklin	5–81	74.6	73.6	74.1	86.5	42.2	41.9	46.1	1.3	8.8%	2.4%	0.72%	600	1.20%	140	0.10%	38.1	98.8
Lancaster	11–81	44.3	44.0	44.4	66.8	42.6	42.4	52.9	0.78	0.65%	0.46%	0.14%	350	<500	34	230	43.4	98.4
York	16–81	91.1	89.8	90.4	95.6	79.2	79.8	53.2	0.86	1.8%	870	520	*290	<500	120	69	43.7	99.8
York	16B–81	87.5	87.6	86.1	93.7	75.7	73.9	53.5	0.86	1.9%	390	520	*250	<500	120	67	43.7	100.1
York	17–81	95.6	94.4	94.7	97.9	93.3	93.5	54.3	1.3	2.6%	0.46%	0.11%	<100	0.18%	28	220	42.8	101.8
Pure limestone								56.0									44.0	100.0
Pure dolomite								30.4	21.9								47.7	100.0

[1] Chemical results are in parts per million unless otherwise indicated (100 ppm = 0.01%).

< Indicates that the result is less than the given value.

* Indicates that the result is near the detection limit and must be interpreted accordingly.

Table 8. *Data for All Samples Tested*

County	Lab no.	Name and location	Quadrangle	Latitude and longitude	Geologic unit	Sample type and interval	Comments
Adams	3–81	Abandoned Gardner quarry, York Springs, Latimore Township	Dillsburg	40°00′28″N 77°06′14″W	Tomstown(?) Formation	Composite face, about 18 ft (5.5 m) of stratigraphic section	Calcareous marble containing diabase intrusions and breccia zones
	12–81	Active Bethlehem Mines Corporation quarry, north of Hanover, Oxford and Conewago Townships	McSherrystown	39°50′00″N 77°02′00″W	Kinzers and Ledger Formations	Composite muck pile	Calcareous marble; tectonic breccia common
	13–81					Composite face, about 35 ft (11 m) of stratigraphic section	Calcareous marble exposed in access ramp; bedding attitude is N5°E, 65°SE
	14–81					Composite face, about 24 ft (7.5 m) of stratigraphic section	Calcareous marble separated from sample 13–81 by 18 ft (5.5 m) of gray limestone
	15–81					Composite face, about 38 ft (11.5 m) of stratigraphic section	Calcareous marble; nearly vertical bedding(?)
Chester	1–81	Abandoned Poorhouse quarry, Embreeville, West Bradford Township	Unionville	39°56′34″N 75°42′56″W	Cockeysville Marble	Composite face, about 40 ft (12 m) of stratigraphic section	Dolomitic marble; subhorizontal bedding; water-well data suggest surrounding floodplain is also underlain by marble
	2–81	Abandoned Pusey's quarries, Kennett Square area, East Marlborough Township	Kennett Square	39°51′54″N 75°44′30″W	Cockeysville Marble	Composite grab sample of three minor float and/or outcrop occurrences	Dolomitic marble; badly overgrown pits about 25 ft (8 m) deep; rare exposures

Table 8. *(Continued)*

County	Lab no.	Name and location	Quadrangle	Latitude and longitude	Geologic unit	Sample type and interval	Comments
Chester	6–81	Abandoned Landenberg quarries, Landenberg area, London Britain Township	West Grove	39°45′29″N 75°46′36″W	Cockeysville Marble	Composite face, about 35 ft (10.5 m) of stratigraphic section	Dolomitic marble; weathered face, southeast corner of pit; bedding attitude is N65°E, 33°SE; very coarsely crystalline
	7–81					Composite face, about 10 ft (3 m) of stratigraphic section	Dolomitic marble; northwest corner of pit
	8–81	Abandoned Needham quarry, West Grove, London Grove Township	West Grove	39°50′20″N 75°49′38″W	Cockeysville Marble	Composite from two minor exposures (float or outcrop) on north slope of pit near water level	Calcareous marble; quarry overgrown; rare exposures
	9–81	Abandoned Acme-Baker quarry, Baker, London Grove Township	West Grove	39°50′24″N 75°40′39″W	Cockeysville Marble	High-grade composite from waste dump on northwest side of quarry	Dolomitic marble; water-filled and overgrown quarry; samples may have been collected from dimension-stone waste pile
	10–81					Composite ledge, about 3 ft (1 m) from northeast exposure in quarry	Dolomitic marble; sampled to determine physical characteristics of typical gray, phlogopite-rich marble
Cumberland	18–81	Active Hempt Brothers quarry, Eberlys Mill, Lower Allen Township	Lemoyne	40°13′14″N 76°54′20″W	St. Paul Group	Composite face, about 25 ft (8 m) of stratigraphic section	Calcareous marble; flinty and sheared appearance; bedding attitude is N55°E, 30°SE

Franklin	4–81	Roadcut east of Marion, Guilford Township	Greencastle	39°51′28″N 77°39′28″W	Rockdale Run Formation (basal unit)	Composite roadcut, about 13 ft (4 m) of stratigraphic section	Limestone, marble-like; sampled to determine if light, varicolored limestones have potential for use as whiting
	5–81	Abandoned marble prospect southeast of Clay Hill, Antrim Township	Greencastle	39°48′00″N 77°39′39″W	Zullinger Formation	Grab samples from pasture and barnyard	Varicolored limestone, marble-like
Lancaster	11–81	Active Lancaster Lime and Stone Corporation quarry, southwest of Schoeneck, West Cocalico Township	Ephrata	40°14′13″N 76°10′51″W	Annville Formation	Composite face, about 90 ft (27 m) of stratigraphic section; third and lowermost lift	Limestone, gray, high-calcium type; beds are nearly vertical and strike east-west
York	16–81	Abandoned Laucks quarries, West York, Manchester Township	West York	39°58′55″N 76°45′27″W	Kinzers Formation	Composite face, about 23 ft (7 m) of stratigraphic section, from east part of southwest pit	Calcarcous marble; exceptionally white bed about 3 ft (1 m) thick near floor; saccharoidal; pink fracture fillings
	16B–81					Composite of muck pile and west face of easternmost pit, about 19 ft (6 m) of stratigraphic section	Calcarcous marble, saccharoidal; rare blebs that appear to be hematitic
	17–81	Active White Pigment Corporation quarry, West York, West Manchester Township	West York	39°56′15″N 76°46′58″W	Kinzers Formation	High-grade composite from muck pile in western portion of pit, north face, lowermost development	Calcareous marble; bedding is obscure

ISBN: 0-8182-0024-3

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